Considerations of the Role of Water in Economic Growth and Development

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CONSIDERATIONS OF THE ROLE OF WATER IN ECONOMIC GROWTH AND DEVELOPMENT

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ABSTRACT

This thesis aims at analyzing the impact of water on economic growth and economic development. We explore different topics that are directly linked to the availability of water, which directly influence economic growth and development. The thesis consists of four studies. The first study models the effect of water utilization and water pollution on economic growth. The second study is based upon reflections on the fixed effects model and makes the distinction between the impact of the mean of a variable X and deviations from that mean on another variable Y. To date it has tended to be assumed that these impacts are the same; we argue that this is not always the case that countries can to an extent adjust to a specific water environment. However having adjusted they face problems when the water environment deviates from the mean. In the third study we explore the effect of different socio economic factors such as labour productivity, agricultural inputs, population density, water resources per land, and variables such as the trade regime, on water withdrawal for the agricultural and non-agricultural sectors. A specific focus is on the interactions between these two sectors. This study is new in its content and its theme of the work. We argue that many global trends will put increasing pressures on agricultural and non-agricultural water use. But there is also potential for increased efficiency in this use. The fourth study tries to fill the gap in the literature that deals with development aid for water and sanitation. We explore the impact of aid and aid volatility on safe access to water and sanitation, using a newly available OECD/DAC data base. Specifically, we analyze both the recipient countries and the donors to determine the role of aid in affecting safe access to water and sanitation.

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LIST OF ABBREVIATIONS

AQUASTAT	FAO's global information system on water and agriculture
BOD	Biological Oxygen Demand
CMED	Commission mondiale de l'environnement et du développement
CO_2	Carbon dioxide
DAC	Development Assistance Committee
DFID	The Department for International Development
EKC	Environmental Kuznets curve
FAO	Food and Agriculture Organization
Fe	Fixed effects
GDP	Gross Domestic Product
GWP	Global Water Partnership
GWSSAR	Global Water Supply and Sanitation Assessment Report 2000 of the Joint Monitoring program
ICWE	International Conference on Water and the Environment
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
IV	Instrumental variable
MDG	Millennium Development Goals
NGO	Non-Governmental Organization
ODA	Official development assistance
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least square
p.c.	Per Capita
Re	Random effects
UN	United Nations
UNESCO	United Nations Educational Scientific and Cultural Organization
UNFPA	United Nations Population Fund
UNDP	United Nations Development Program
WCED	World Commission on Environment and Development
WDR	World Development Report
W&S	Water and sanitation
WSSCC	Water Supply and Sanitation Collaborative Council
WWC	World Water Council
WWDR	World Water Development Report
WWF	World Water Forum

Chapter 1

General Introduction

"Man is a complex being; he makes desserts bloom and lakes die"

Gil stern

What determines water scarcity[1]? What is causing stress on water resources? And how to assure that there can be a sustainable development without understanding the role of water in economic development and growth? Although answering these questions may seem easy, it is quite complex to summarize all the kinds of causes and interactions between humans, nature and businesses.

1.1 Background

1.1.1 Urbanization, population growth and water

Developed and developing countries are facing rapid urbanization at a fast pace. Rapid urbanization causes problems such as stress on water resources, poor sanitation, unemployment, poverty, and environmental degradation; Water Aid highlighted water and sanitation as a pressing issue that dilutes the efforts to reach the MDG goals. The UN projected that the urban population is going to be concentrated highly in Asia and Africa, and most urban populations still lack safe access to water and sanitation that affects health and the health sector. The average annual growth in population according to the UN will be 1.1 % between 2010 and 2015.

[1] Water scarcity can be the lack of enough water or lack of access to safe water. In other words, water scarcity embodies water quantity and water quality. The UN defines water scarcity as the point at which the aggregate impact of all users impinges on the supply or quality of water under prevailing institutional arrangements to the extent that the demand by all sectors, including the environment, cannot be satisfied fully. Water scarcity is a relative concept and can occur at any level of supply or demand. Scarcity may be a social construct (a product of affluence, expectations and customary behaviour) or the consequence of altered supply patterns - stemming from climate change for example. https://www.un.org/waterforlifedecade/scarcity.shtml. (Accessed December, 2010).

The urban population accounts for 50.5 per cent of the total population, that means more than half of the world's people live in urban areas and this percentage is expected to reach 65 per cent in 2030 (United Nations, 1990; 1991). Another revision of the official United Nations population estimates and projections (2007) speculated an increase in population to 9.2 billion by 2050. However, more than 90 per cent of future population growth will be concentrated in cities in developing countries. In some areas, rapid urbanization and economic growth are held back due to water scarcity, even though they obviously have not reached their full potential. On the other hand, rapid urbanization has already caused serious water shortage and severe conflicts over water demand and supply. Water has become a key restricting factor of the urbanization process, as well as to socio-economic development (Varis and Vakkilainen, 2001; Okadera *et al.*, 2006).

A global water crisis is just one of several pressing future problems (Biswas, 1991). According to statistics, global water withdrawal increased by eight times in the 19th century and doubled in every 15 years. Water withdrawal for different economic sectors, agriculture, industry and domestic has increased by 7, 20 and 12 times respectively. For example, starting from 1940, observations show that the annual global water withdrawals have increased by an average of 2.5% to 3% a year compared with annual population growth of 1.5% to 2%. In developing countries over the past decade water withdrawals have been increasing by 4% to 8% a year. Figure (1.1) gives the FAO's 2003 estimation of the water withdrawal ratios at a global level, the withdrawal ratios are 70 % agricultural, 11 % municipal and 19 % industrial respectively. Yet water is a finite resource (Seckler, 1994, p. 70-71). This cannot go on indefinitely and already there are enormous strains in many areas of the world.

According to the World Water Council and the initial preparation for the Johannesburg Summit (2002) the fact that the world's population tripled in the 20th century increased the use of renewable water resources by six-fold. People are withdrawing water from rivers, lakes, and underground sources faster than they can be renewed; as a consequence, unsustainably pulling out what was once a renewable resource. Currently, according to the 3rd UN World Water Development Report

(2009), 31 countries mostly in Africa and the Near East face water stress or water scarcity. Therefore, in many parts of the world millions of people are in a desperate need of drinking water. The poor people of the developing countries are the largest to be affected by the water crisis. Therefore, in some parts of the world it is not the shortage of petroleum that citizens have to worry about, but the shortage of drinking water.

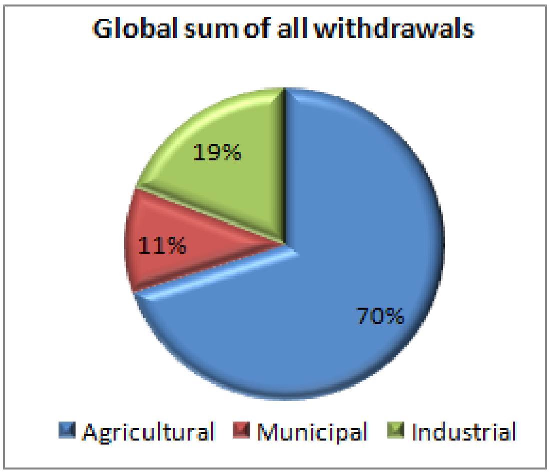

Figure 1.1: Water withdrawal ratios by sector at global level, around 2003
Source: FAO- AQUASTAT- water use

1.1.2 Climate change and water resources

Water is a renewable resource. Its presence and availability in any region is related to several factors, e.g. the geography, climate change, and also the biological and the physical conditions that dominated the area (Barua, and Hubacek, 2008). The Intergovernmental Panel on Climate Change (IPCC, 1996a) made a presumption that climate change is caused by the increasing concentration of greenhouse gasses, these in turn cause the increase in surface temperature, which affects the ecosystem and the hydrological cycle. That is evident in the continuous episodes of rainfall fluctuations, droughts and floods around the world, that in turn add stress to the water resources, contributing significantly to the water crisis. Table 1.1 contains a vision of the water availability per capita for 21 countries provided by the IPCC. The table contains actual data and projected values for the water availability stressed by population growth and climate change. The data in the table depicts the fact that water availability decreases in countries that suffer from high population growth amid different climatic scenarios.

Table1.1: water availability (m^3/yr) in 2050 for the present climatic conditions and for different transient climatic scenarios.

Country	Present Climate (1990) Water availability per capita	Present Climate (2050) Water availability for current climate change with the effect of projected population to year 2050	Scenario range (2050) Water availability with projected climate change and population growth
China	2,500	1,630	1,550-1,780
Cyprus	1,280	820	620-850
France	4,110	3,620	2,510-2,970
Haiti	1,700	650	280-840
India	1,930	1,050	1,060-1,420
Japan	3,210	3,060	2,940-3,470
Kenya	640	170	210-250
Madagascar	3,330	710	480-730
Mexico	4,270	2,100	1,7140-2,010
Peru	1,860	880	690-1,020
Poland	1,470	1,250	980-1,860
Saudi Arabia	310	80	30-140
South Africa	1,320	540	150-500
Spain	3,310	3,090	1,820-2,200
Sri Lanka	2,500	1,520	1,440-4,900
Thailand	3,380	2,220	590-3,070
Togo	3,400	900	550-880
Turkey	3,070	1,240	700-1,910
Ukraine	4,050	3,480	2,830-3990
United Kingdom	2,650	2,430	2,190-2,520
Vietnam	6,880	2,970	2,6680-3,140

Source: IPCC, *1996b*, page *478*

1.1.3 Human, Food security and water resources

The Human Development Report (1994) emphasised the importance of human security as a contributor to development. The UN Human Development Report (2006, p.3), addressed the term water security as a part of human security *"In broad terms water security is about ensuring that every person has reliable access to enough safe water at an affordable price to lead a healthy, dignified and productive life, while maintaining the ecological systems that provide water and also depend on water. When these conditions are not met, or when access to water is disrupted, people face* *acute human security risks transmitted through poor health and the disruption of livelihoods".*

Water security is an important component of food security, economic security, eco-security, social security, national security, and even human survival security, especially in dry and semi-dry areas (Knapp, 1995). Water is, truthfully, the source of life on earth. The human body is 70% water. So far, beyond the impact of population growth, the demand for freshwater has been rising in response to industrial development, increased irrigated agriculture, huge urbanization, and rising living standards.

The Toronto 2010 summit gave objective results. The G20 countries' declaration and commitment to the Global Agriculture and Food Security Program in fulfilment of the Pittsburgh commitment of 2009 on food security assisted their plan to put into action the Global Partnership for Agriculture and Food Security. This particularly contributes by considering the accessing to safe water to be listed as a security issue. The United Nations announced the start of the action "Water for Life" as a mean for achieving the Millennium Development Goal for the easy access to safe drinking water and proper sanitation, i.e. by 2015 people who are subjected for access to unsafe water and bad sanitation would be reduced by a half.

The United Nations declared the twenty second of March 2005 as the world water day; they announced the start of the action Water for Life as a mean for achieving the Millennium Development Goal (MDGs) for the easy access to safe water and good sanitation. The action decade spans from 2005 until 2015. By 2015 people who are subjected for access to unsafe water and bad sanitation would be reduced to the half. These goals were reported and agreed on in the World Summit on Sustainable Development in the Johannesburg (2002) plan to implement this MDG. MDGs are first and foremost about human development that consequently leads to economic development. Human development depends on the presence of water; the shortage of water can hamper the progress in decreasing poverty by half by 2015. Poor health and children's deaths due to lack of safe access to water and proper sanitation, affects economic performance and development as well.

1.1.4 The carrying capacity and sustainable development

The Second Law of thermodynamic states that: highly-ordered systems grow *"at the expense of increasing the disorder at higher levels in the system's hierarchy"* (Schneider and Kay, 1992, p.25). The systems are considered as complex dynamic systems always in a non-equilibrium state to survive their interior ordering against the entropic[2] decay, they should consume a continuous input of matter- energy. Several reasons lie behind the logic in linking the second law of thermodynamics with the human carrying capacity. In particular, the human economy is open, unstable, dynamic and subject to continuous changes. The interaction between the population growth, economic growth, investment, technology and productivity on one side and the environmental deterioration and natural resource depletion on the other side, creates a long run link between the economy and the natural environment. Employing a material balance perspective on the economic procedures, can be critical to represent these environmental issues.

From an ecological perspective, adequate land and associated productive natural capital are important to existence on Earth. However, at extant, both the human population and average consumption are increasing while the total area of productive land and stocks of natural capital are fixed or even in decline. These facts call for a reconsideration of the carrying capacity analysis in sustainable development planning. *"An environment's carrying capacity is its maximum persistently supportable load"* (Catton, 1986). Despite our technological, economic, and cultural achievements, achieving sustainability requires that we understand human beings as ecological entities. Indeed, from a functional perspective, humans consume energy and material resources extracted from nature for their basic needs and the production of artefacts and these in the end are given back in degraded form to the ecosphere as waste (Rees, 1996).

The total water resources should be rationally allocated, (Figure 1.2) depicts the allocation of renewable water resources for the globe. However, so far, the most

[2] "Entropy" is a measure of unusable energy within a closed or isolated system (the universe for example).

endangered ecosystem in the world is the freshwater one, biodiversity registered greater decline in fresh water than in any other ecosystem (Sala *et al.*, 2000). The socioeconomic development should follow the principle of sustainable development and realize a benign circle of eco-environment. *"Carrying capacity is the fundamental basis for demographic accounting"* (Hardin, 1991). Nevertheless, conventional economists often fail to take into consideration the carrying capacity concept. Their vision of the economy is often one in which *"the factors of production are infinitely substitutable for one another"* and in which *"using any resource more intensely guarantees an increase in output"* (Kirchner *et al.*, 1985). As Daly (1986) noticed, this vision assumes a world *"in which carrying capacity is infinitely expandable"* (and therefore irrelevant).

Total actual renewable water resources per inhabitant (m^3/year)

Actual renewable surface water and groundwater resources per inhabitant (in 2005)

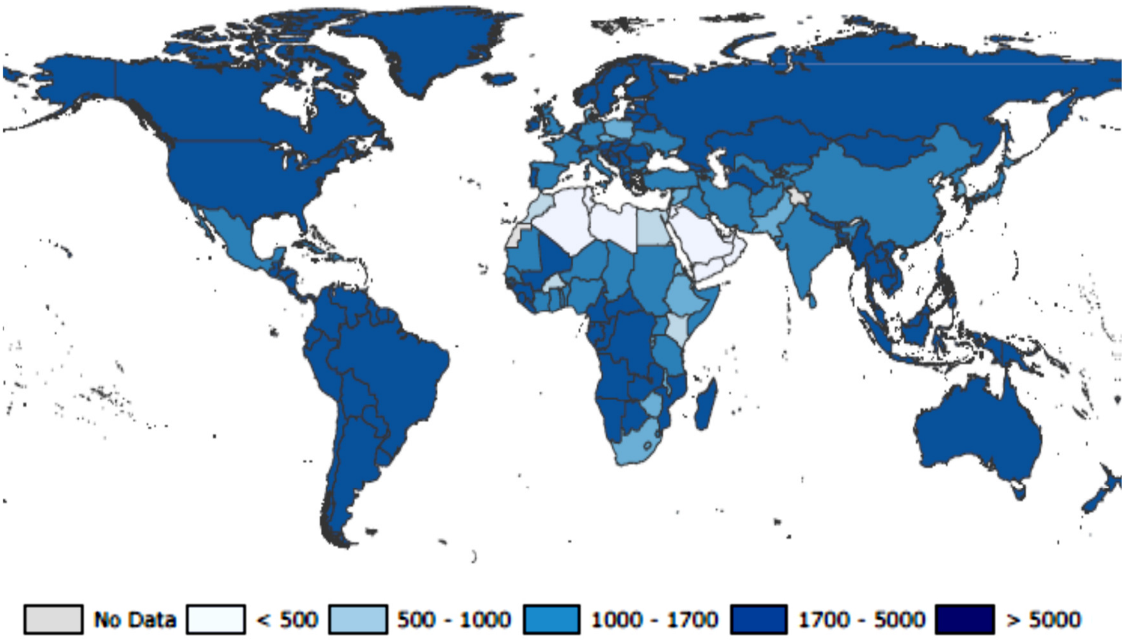

Figure 1.2: Total actual renewable water resources per inhabitant (m^3/year). Actual renewable surface water and groundwater resources per inhabitant (2005)
Source: FAO-AQUASTAT, 2008.

1.2 Water as a factor in economic growth and economic development

The supply of freshwater available to humanity is shrinking, in part, because many freshwater resources have become increasingly polluted. In some countries lakes and rivers have become containers for wastes, including untreated or partially treated municipal sewage, toxic industrial effluents, and harmful chemicals leached into surface and ground waters from agricultural activities.

Therefore, in many parts of the world millions of people are in a desperate need of drinking water. Regrettably enough, however, the large part of the world that is under water crises is the poor people of the developing countries- although in part perhaps this is why they are poor. Even within the developing world, it is the poor individuals who suffer the most from water stress. Rich ones can always afford to buy their need of water.

The World Bank warns that the lack of fresh water is proving an increasingly pressing factor limiting the development in the developing countries. This puts the poor countries in a trap finding their selves caught between finite and increasingly polluted water supplies on the one hand and rapidly rising demand from population growth and development on the other. Therefore, many developing countries would face uneasy choices in their development plans according to the population report (1998), which is issued by the Population Information Program. In the 21st century, the world as a whole will face a problem whether to allow the water consumption level to continue increasing or to place a limit on the water consumption.

International institutions and governments have started to be aware of this water crisis. In 1999 the United Nations Environment Programme (UNEP) declared the identification of the world water shortage as one of the most persisting issues for the new millennium. This identification came as an outcome for an effort done by 200 scientists in 50 countries that called for considering humanity at the verge due to a shortage of clean water, where at that time 20% of the world's population lacked access to safe drinking water and 50% lacked access to safe sanitation. They launched the Global Environment Outlook 2000 (GEO-2000) which is often considered as the strongest valuation of the environmental crisis facing humanity in the new millennium. The problem of water shortage worried the World Meteorological Organization which estimates that if the consumption patterns persist, the problem is going to be worsening by 2025 when two out of three people will suffer in their access to safe water. The reality is likely to be worse with the climate change effects, especially those associated with the El Niño that demands more increased efficient management of water resources. Figure 1.3, illustrates the water withdrawal facts in different regions in the world. From the figure we can see that the highest percentage of the withdrawal with respect to the local water resources is occurring in the Middle East, North Africa, and some parts of central Asia, where the percentage exceeds 75% of the natural water resources.

Proportion of renewable water resources withdrawn (MDG Water Indicator)

Surface water and groundwater withdrawal as percentage of total actual renewable water resources (around 2001)

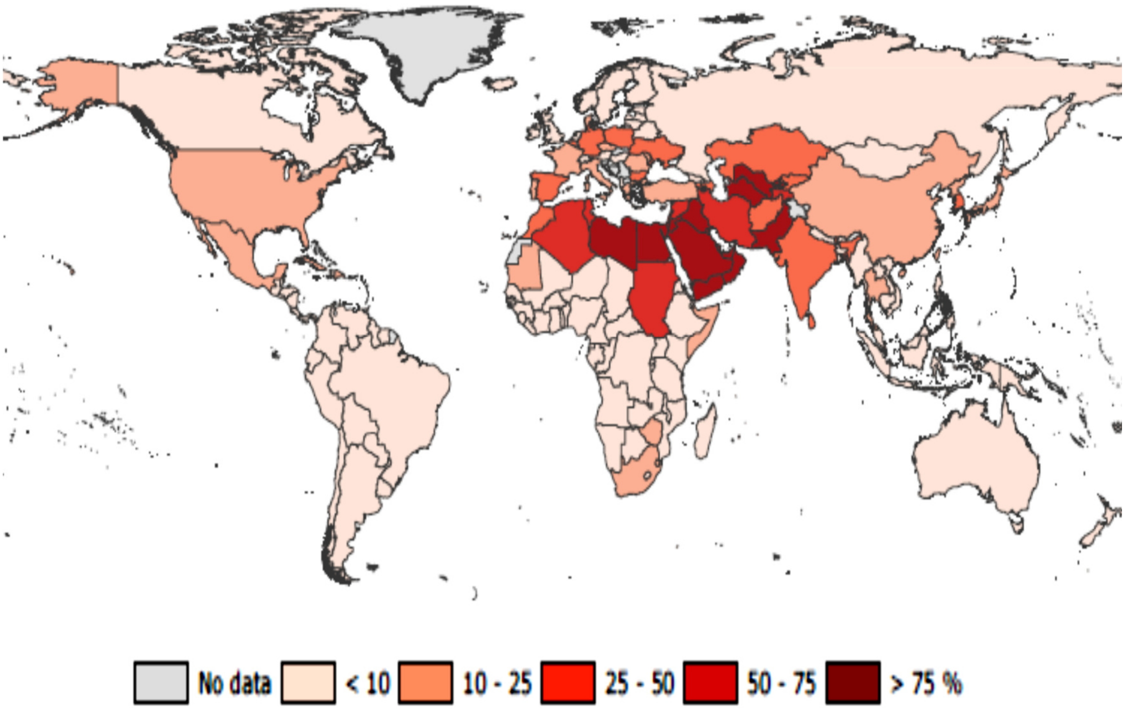

Figure 1.3: Proportion of renewable water resources withdrawn (MDG Water Indicator) Surface water and groundwater withdrawal as percentage of total actual renewable water resources (around 2001). Source: FAO-AQUASTAT, 2008.

In 2011, the World Water Day focused on the impact of urbanization, population growth, industrialization and effects of climate change, conflicts and natural disasters on urban water systems. Moreover, this sent a massage to motivate governments, organizations, communities, and individuals globally to take actions and find solutions for urban water management.

The report by the Stockholm International Water Institute (SIWI, 2005) "Making water a part of economic development" defines the concept that dedicates the role of water in the economy *"Water and economy are inextricably linked. A country's overall development strategy and macroeconomic policies- including fiscal, monetary and trade policies- directly and indirectly affect demand and investment in water-related activities. Perhaps the most obvious examples are reforms to trade and agriculture that affect terms -of – trade and production and cropping patterns and thus ultimately determine water resource use and allocation"* SIWI (2005, p.7).

The report embodies five important messages for decision makers; four of these messages insist upon the importance of improving water resources and proper sanitation. The first two messages highlight the importance of improving water and sanitation in addition to the economic benefits from that action for which trading off the investment costs can be critical. The third message brings to the front line the importance of the connection between economic performance and fluctuations in rainfall, pointing at the relationship between the GDP and the rainfall. The last two messages mention the importance of water and sanitation to improve economic productivity, and the last message emphasis the challenge of water management together with improving water resources and sanitation. Of course, these messages have a greater possibility of being implemented if governments and international institutions work together to develop their modus operandi to bring about the desired results.

Starting from these messages, we build our work on exploring the different factors that may determine the effects of water resources on economic development, economic growth and security. The first step to underline the position of water in the economy is to consider its economic value. This work highlights the importance of water as an economic good and as a social good in the economic development. It is relevant that water is considered by some literature as a public good subject to congestion. Several studies modeled water effects on growth. One of the most critical studies is by Barbier (2004). He modeled the influence of the rate of water utilization on the endogenous economic growth by building upon the congestion model of economic growth introduced by Barro and Sala-I-Martin (1992, p. 650).

The economic development in developing countries is impacted upon by the development of water resources and sanitation. Poor sanitation affects the health of an important factor of production, labour. Good health manifestly facilitates the education sector in improving the quality of labour. Developing countries depend on the international bilateral and multilateral aid to improve the infrastructure and to enhance the performance in different economic sectors. Clearly, aid and aid volatility play a critical role here in improving the water and sanitation in developing countries, although aid volatility may hamper efforts to reach the MDG's by 2015.

Poverty, economic recessions and low incomes play an important part in changing regimes and in setting off national wars. Rainfall as mentioned in the third message plays a critical part in the economic cycle. Rainfall, the green water, absorbed in the soil, impacts on the production of 60% of the world's food and can have a dramatic effect due to its fluctuations. This effect impacts on food security, consequently on human security, and explicitly on democracy. Food security is a pressing issue especially in developing countries that need to cope with the growth in population. Agricultural irrigations and exploitation of ground water in their place are affecting badly on the ecosystem. Finally, water resources, ecosystem, economic development, economic growth, human security, food security, democracy and climate change, are all linked in a complex chain. Superficially, it may appear that they are not connected, but trials and observations suggest their interconnection and their interdependence as well. The biggest challenge to reach the MDG's is to improve standards of living, achieve better education, socio economic advancements, that consequently would lead to a slowdown in population growth.

1.3 Thesis Outline and Contributions

Water is a wide topic. In our work, we are concentrating on the role of 'blue' water (withdrawn from rivers, lakes and aquifers). In general, the FAO's 23rd (2003, p.3) water report stated that *"The concept of water resources is multidimensional. It is not limited only to its physical measure (hydrological and hydrogeological), the 'flows and stocks', but encompasses other more qualitative, environmental and socio-economic dimensions"*. Building upon all the previous facts, we endeavour to introduce four seemingly independent research tasks, studies that use frameworks to explore the effect of water on economic growth and economic development. Each study is independent and contains its literature review, data, methodology and modeling framework. The work in general, consists of six chapters as detailed below:

Chapter 1. General Introduction

The introduction contains some brief ideas as a preface for the contents in our work and statistics related to our topic, in addition to the thesis outlines, i.e. this chapter. In emboldened text we highlight some of the major conclusions.

Chapter 2. Water Utilization, Water Quality and the Endogenous Economic Growth

In chapter 2 we attempt to model the effect of the ratio of water utilization together with water quality on the economic growth within a macroeconomic framework. Most of the previous literature modelled the effect of water withdrawal and water use on economic growth without taking into consideration the fact that depletion of resources due to pollution is affecting both, water withdrawal and growth. Put simply in order to model the impact of water withdrawal we need to include water quality, just as when modelling we should model both labour and its quality. We used GDP per capita, percentage of growth and the rate of five years growth as three dependent variables to be regressed on our variables of interest using a panel data analysis, with both the fixed and the random effects. **The major conclusion from this part of the analysis is that both water quantity and water quality impact upon growth.**

Indeed it can even be argued that the impact of water quality is the greater of the two. In a sense this is good news as water quality may be easier to 'fix' than water shortage. However, in this we noticed that we got a difference between coefficients of estimations from different techniques. This raised further issues which are discussed and explored in details in chapter 3.

Chapter 3. Reflections on Fixed Effects

To investigate the difference in the coefficients in the panels of the regression analysis in chapter two from fixed and random effects, we reflect on the nature of fixed effects. We argue that this involves an implicit, seldom stated and never tested assumption that the impact of the country mean of a variable X is the same as the impact of deviations from that mean within a regression context. This is something we test for and suggest an alternative approach which in many respects combines fixed and random effects. The method is present in details in this chapter. **The major conclusion that arises from this is that the impact of water utilization and water quality, as well as other variables, have different effects depending upon whether we are referring to the mean value or variations around the mean. The evidence suggests that to an extent economies are able to adjust to low, or high, water availability/quality. But they are much more susceptible to variations around this mean. To the extent that climate change may not just increase/decrease average rainfall, but also lead to greater variability, this can cause problems for the future.**

Chapter 4. Effect of Socio Economic Productivity on Water Withdrawal

Chapter four is a complimentary work for the topic started in chapter two. In chapter two, we explored the effect of the water on the economic growth. In this chapter we examine the different socio economic factors that impact on water withdrawal in different economic sectors. This implicitly models the competitiveness between economic sectors for the water resource. This emphasises the need of better water management to enhance economic productivity in different economic sectors, which creates the proper environment for the economic development. **The major**

conclusions that arises from this include water demand from agricultural and non-agricultural purposes are complementary, with an increase in one being linked to an increase in other. This could reflect supply side factors. But the contradictory impact of other variables such as trade, also suggest the competitive nature of the demand for water, given finite resources, between different users.

Chapter 5. Safe Access to Water and Sanitation

Safe access to water and proper sanitation is one of the great human development challenges of the early stages of 21st century. After discussing the interdependent relationship and the role of water in the economic development as well as the productivity of different economic sectors, we explore the effect of aid and aid volatility on the safe access to water and sanitation, using recently availably DAC/OECD data. This is the 7th band in the millennium development goals, after the awareness that countries cannot have development and cannot reach the goals without these basics. **The major conclusion that aid allocation by donors is focused on governments with higher governance indicators and the poorer the country the higher the allocation of aid for water and sanitation subsectors. That indicates a degree of consistency between the donors and the recipients. Water and sanitation aid is working while its volatility is affecting negatively on the safe access to water and proper sanitation, at the same time, although aid is working for water access, basic sanitation still need more attention from the international society.**

Chapter 6. Conclusions, General Summaries and Policy Discussions

This chapter includes a general summary of each study with some interventions. In addition to the discussions of the international policies and some contributions. **The discussions involve several successful methods and examples that are applied for water management and solutions to use water efficiently. Different solutions can be applied such as proper water pricing, development of a good institutional system that can apply the most appropriate policies, in addition to the important**

role of technology in water disposal treatments and irrigation water management.

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Chapter 2

Water Utilization, Water Quality and the Endogenous Economic Growth

2.1 Introduction

The realization that water has an impact on the economic growth has triggered the need to emphasize and understand the role of water on the economic growth. According to the Pacific Institute (2007), the scarcity of freshwater is *"already an economic constraint in major growth markets such as China, India, and Indonesia, as well as commercial centres in Australia and the western United States"* (the Pacific Institute, 2007, p.5). According to the estimates, \$38.2 billion to \$51.4 billion a year for water supply and wastewater treatment is what China and the Asian developed countries need (UNESCO- WWDR, 2009). The third United Nations World Water Development Report specifies, as well, the direct economic benefits of investments in water systems, especially in the developing countries where water shortages are hampering economic growth.

Global warming has impacted on several regions especially the arid and semi-arid lands, the fluctuation in rainfall, the population growth and the lack of proper management of the water resources added up to stress on water resources leading to the fact that just 1% of the water resources available on earth is freshwater (UNESCO- WWAP, 2003). The recognition that human behaviour has an impact on water, and on the global ecosystem, increases the need to adjust that behaviour in order to stabilize and sustain our future (WCED, 1987).

But first we must understand human behaviour and its impact in this context. This chapter is based on examining both the impact of water utilization together with the effect of water quality or water pollution which is expressed as BOD (Biological Oxygen Demand) on the economic growth. The analysis is done by pooled panel regression for 177 countries, the impact of our variables of interest are studied within a macroeconomic framework. The chapter surveys the effect of water on the economy by monitoring different indicators that reflect national and international economies and which exert a pressure on the environment at the same time.

2.2 Role of water in economic growth

2.2.1 Economic growth, climate change and the natural resources scarcity

A substantial literature has pointed to the interdependence of the water resources and the economic growth. Shafik and Bandyopadhyay (1992) investigated this relation by exploring the environmental transformation for countries corresponding to different incomes within a macroeconomic perspective, by using the environmental indicators as dependent variables in panel regressions with data from 149 countries for periods from 1960- 90. They found that water and sanitation improve with increases in per capita income; moreover, they explored the policy effects across countries for the effect of income and concluded that income has the highest significant effect on the water and sanitation of the variables analyzed.

From another perspective, forecasts of fresh water resources revealed the increasing awareness that the world is on the verge of an upcoming water crisis. Several studies reflected the diminishing supply of fresh water (Seckler *et al*., 1999; Vörösmarty *et al*., 2000). However, there is a debate about the direct causes of the water crisis. So far the most pressing issue from the economic standpoint is the effect of diminishing water resources on the income per capita as considered by Barbier (2004). He ran an international growth model to explore the effect of water constraints on economic growth to find that water utilization is not constraining growth for all countries Booker *et al.* (2012). For the fact that, Barbier's results (Barbier, 2004, p.2) recommend some reconsiderations towards previous studies which claimed that by 2025, at least 17 countries will be subjected to severe water scarcity[3] and about 24 countries are going to face economic water scarcity (Seckler *et al*., 1999; Cosgrove and Rijsberman, 2000). Freshwater scarcity is considered by both scientists and politicians as the second most important environmental issue of the 21st century (United Nations Environmental Programme's (UNEP) Global Environmental Outlook, 2000). According to the United Nations' population projections, the World Population Prospects (2008), the world population is expected to reach 9 billion in

[3] Water scarcity, according to the UN, is the imbalances between availability and demand, the degradation of groundwater and surface water quality, intersectoral competition, interregional and international conflicts, all contributes to water scarcity. www.fao.org/nr/water/issues/scarcity.html.

2050. Water demands of the domestic and industrial sectors will increase in the future, even regions that do not have water scarcity problems today may face water scarcity or restriction for agricultural development and this can cause a critical state in food security.

International efforts focused on the importance for development and poverty elimination in order to achieve the MDGs by 2015. Very few recognized the role of water, even for poor water developing countries, and its importance as a major factor in determining income and economic growth, nor recognized the role of water as an important catalyst for development and poverty reduction (Sullivan, 2002). The interaction and the interdependence between the economic development and water scarcity are in part governed by the population increase, urbanization, and economic advancement. These pressures can be relaxed with technical advancements and possibly by substitution if there are such possibilities. So far, however, water as an input in production is proving to be irreplaceable. The economic growth is generally depending on inputs of production; once these inputs are limited they can limit the economic growth. The fact that water is an irreplaceable input makes it subject to inelastic demand.

2.2.2 The contribution of different water uses to economic development and the importance of water management

Population and economic growth increase the stress on the water resources, the water resources are finite but the demand cannot be considered as finite. Welfare and increasing living standards add a burden for the water resources. We cannot separate the economic and the social development from the efficient management of the water resource. The benefits from economic growth are accompanied by environmental degradations. The statistics reflect a relation between high income per capita and high level of water consumption. Table 2.1 contains data that reflect the fact that water resource availability, or lack of it, is linked to economic and social progress that is represented by the GDP per capita, meaning that development is likely to be influenced by how water resources are managed. According to Sullivan (2002) if there is water poverty any measures to reduce income poverty are unlikely to be successful.

Table 2.1: Water use and national income

Annual Water Withdrawals per capita (m^3)					
	Gdp p.c. (constant 2000 USD) (World Bank)	Agricultural	Industrial	Domestic	Total
Tanzania(2000)	273.81344	120	0	14	135
Sri Lanka (2000)	872.66552	579	15	14	608
South Africa (2000)	3019.9466	166	16	82	264
UK(2002)	26053.552	21.9	120.6	118.9	261.5*
Sweden(2002)	28753.85	26	161	109	296
USA(2000)	35080.731	660	736	203	1600

Source: Gleick 2006 (m^3/person/year), *Source: AQUASTAT , 2009 (m^3/person/year)

2.2.2.1 The Demand for water from different economic sectors

About 67% of the global water withdrawal and 87% of the water usage are used for irrigation purposes (Shiklomanov, 1997). Moreover, statistics and projections showed the irrigation water withdrawal per capita is higher than the per capita withdrawal for industrial and domestic sector (Seckler *et al.*, 1999) and is also projected to increase for the period from 1990 until 2025. About 40% of the food produced globally comes from irrigated land (Gleick, 2002).

To depict the situation in future water and food security, it is more appropriate to try to model water requirements of irrigated agriculture to get the desired amount of production. Modelling water for agriculture as a function of irrigated area, climate, and crops provides the basis for estimating the future impact of climate change as well as demographic, socioeconomic, and technological changes (Döll and Siebert, 2002). Döll and Siebert developed a global model of water resources and water use calling it Water GAP (Water-Global Assessment and Prognosis). They use in their model the required irrigation water to identify water scarcity. In evaluating the irrigation water in developing countries, different cases are registered concerning the lack of water management, In India for example, Shah (1993) documented an exploitation of ground water by the private farmers.

Unemployment, poverty, low productivity in the agricultural sector, all increase the need to address the possible solutions and available actions to reduce the water constraint. The increasing demand for food will enhance the expansions of the irrigated lands and consequently would other things being equal, increase the depletion of the natural resource water. The production of per capita of cereals has not grown much in the face of increasing demand. Although economic development is normally accompanied by improvements in a country's food supply. Figure (2.1) reflects the global withdrawal of water for different economic sectors, which reveals that the highest percentage of water withdrawal in the last decade was for the agricultural sector.

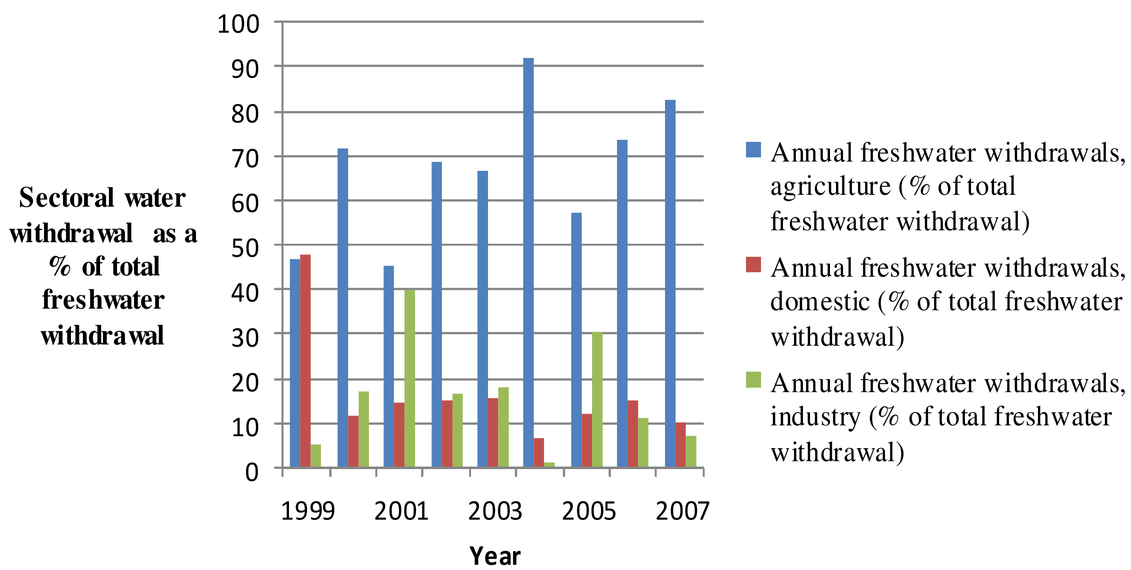

Figure 2.1: Annual freshwater withdrawal for different economic sectors in the world.
Source: World Bank database (2011)

2.2.2.2 Hydropower and growth

In discussing economic growth's dependence on water resources it is useful to mention the importance of water in hydropower. In general, the hydropower is likely to be a common feature in developed countries; the value of hydropower water is not different from that in agriculture in the short run (Gibbons, 1986). The increasing demand for hydropower as a source of energy in the developing countries became a necessity to alleviate the environmental damages accompanied with urbanization and population growth (Goodland, 1996). Briscoe (1996) commented on the role of water in hydro power as an economically sustainable energy source in countries where there is abundance of water and to be an attractive alternative in developing countries where population growth and increasing demand for power based on fossil fuel creates environmental damages and leads to large CO_2 emission. In this sense the use of hydropower represents a global public good. In this sense, water facilitates growth as an energy source.

2.2.2.3 Water pollution and economic growth

In the neo-classical hypothesis, pollution is a public good that generates markets' externalities and failures. We cannot exclude the deterioration of natural resources and pollution as long as we are discussing the effect of water withdrawal on the economic growth. Human activities including urbanization, industrialization together with water pollution are adding stress on the finite water resources. How can societies both sustain their environment and guarantee long term economic growth?

Several studies concluded that the relation between polluting emissions and the GDP per capita takes an inverted U shaped curve, and other studies registered different environmental cases at different income levels (Grosman and Krueger, 1995; Selden and Song, 1994; Shafik and Bandyopadhyay, 1992). Institutions and policies are important to ensure the realisation of sustainable development with targeted economic growth and limited pollution. Governments can apply policies to force pollution abatement by for example, taxes or fines for pollution.

2.3 Water Management

Briscoe (1996) gave his vision which considered water as a scarce resource critical for attaining economic development and environmental sustainability in many countries. He also considered management of the water resources using economic principles. Although the availability of water can place a constraint on the economic growth, the limited water resources may not be too much of a hampering factor for the economic growth as long as the water input in agriculture and industry are allocated efficiently and in a way which maintains environmental sustainability. In general poverty, climate change and the increasing need to access safe water raised the need for critically efficient management of water resources. This issue was discussed in the second World Water Forum[4] that is held in Netherlands in 2000.

Globally, water for agriculture is the most challenging issue with domestic water requirements currently contributing a smaller share in the demand. The statistics in figure 2.1 shows that the agricultural irrigation consumes the highest available water resource even in the most arid countries characterized by rapid population growth and urbanization. Following the fact that over 70 % of the total water supply is consumed in irrigation (Seckler *et al.*, 1999), it is critical to develop the irrigation management system and create different methods to efficiently allocate the future water resources. Otherwise, the required economic growth would be restricted by the need to meet the water demand for other sectors in the economy. Different water characteristics in different ecosystems can be a starting place for sustainable management of water (Sullivan, 2002). Water assessments reflect the need to develop more equitable and sustainable methods of water management by providing information on water demand and trying to satisfy this demand by overcoming the obstacles against supply. Sullivan (2002) introduced a quantified measure of the water poverty in order to give acceptable universal measurements. This is important as financial accountings measures are critical for any successful management strategies. Sullivan (2002) considered demand management as a challenge facing policy makers today.

[4] The World Water Forum (WWF) has been held every three years starting from 1997 and organized by the World Water Council (WWC). It is held with the participation of experts and international organizations related to the field of water.

Industrialization in agriculture and the efforts to meet the food demand led to new inputs that contributed to water pollution and increasing water resource degradation. The fact that production of per capita cereals has not grown much in the face of increasing demand illustrates the problem. A suitable response is innovation and Smulders (2004) discussed how the scarcity of the natural resource should stimulate innovation. i.e. the invisible hand at work.

The demand for municipal water is growing very fast in developing countries and new sources have constantly to be found making the costs of urban supplies grow rapidly. Urban water supplies in some developing countries have been financed out of general revenues and the costs of water utility is fully subsidized in some regions (Briscoe, 1996). Countries that depend on agriculture need irrigation management especially if there is a water scarcity and suffer from water evaporation due to weather circumstances at the same time.

In evaluating the irrigation water in developing countries different cases are registered concerning the lack of water management, In India for example, Shah (1993) documented an exploitation of ground water. Global water resources are limited, therefore, a more sustainable method of water management is needed to support continued provision of water. As for Public irrigation systems, in most of the developing countries charges have been much lower than even to cover operations and maintenance costs (World Bank, 1995). Financial costs of irrigation systems (per unit of water) are much lower than they are for urban water, whereas opportunity costs are much higher (Briscoe, 1996). In Bihar in India, water charges are not sufficient to even cover the costs of collection (Rogers *et al*., 1998).

In industrialized countries, in setting an urban water tariff, the opportunity costs of water are excluded generally from charging. This omission can be taken into consideration with well-functioning systems for water resources management (Briscoe, 1996). The increasing stress on water resources emphasizes the increasing need for efficient management systems and the development of more efficient irrigation systems besides the probability of avoiding plant thirst in arid countries (Sullivan, 2002).

2.4 Water resources management in the context of climate and socio-economic change

The Dublin Conference in 1992[5] concluded that *"since water sustains all life, effective management of water resources demands a holistic approach, linking social and economic development with protection of natural ecosystems"* (ICWE, 1992). Longo and York (2009) recognized the lack of literature that deals with the socio structural factors that affect the water consumption from the perspective that the ecosystem sustainability is influenced by the human social relations. This issue is also highlighted by Catton and Dunlop (1978). All the literature that discussed the social influence on the deforestation, carbon emissions indirectly emphasises the importance of dealing with the sociological influence of water on the global environment; Water resource availability, or lack of it, is linked to economic and social progress. Sullivan (2002) considered the poverty in the society in her assessment of the water poverty index and highlighted the fact that several water projects designed to increase agricultural or industrial production are creating an additional ecological disruption. Several factors impact on the ecological disruption that has resulted from water projects designed to increase agricultural or industrial production, one of which is the rapid urbanization that increases the pollution of the water with nitrates related to runoffs from urban areas and agricultural land.

To manage water under scarcity it is required to implement serious policies that may find difficulties in certain areas of the world especially in the developing countries and in countries that are in national or international conflict, Policies required for development and environmental sustainability can be the effective tools that guide the behaviour in different regions of the world. Policies in general, need good implementation and monitoring to ensure good application and benefits. Many regions that suffer from water scarcity are characterized as being agricultural countries with rapid urbanization. In Jordan, for example, the water demand exceeded

[5] The Dublin Statement on Water and Sustainable Development, also known as the Dublin Principles, was adopted by the United Nations on the 31st of January 1992 at the International Conference on Water and the Environment (ICWE), Dublin, Ireland. This conference was the last technical preparatory meeting before the UN Conference on Environment and Development (the "Earth Summit") in Rio de Janeiro in June 1992. This conference was a meeting of international water experts.

the available supply due to rapid industrialization and population growth. In Qatar, irrigation is concentrated on the groundwater due to the rainfall scarcity that put the aquifers[6]at the risk from being subjected to depletion. Water pollution in Syria results from the lack of efficient sanitation and industrial wastes (Biswas, 1994; Shuval, 1994). From a global viewpoint the paybacks and the benefits from investments in water have exceeded the costs, but the gains could have been more equitably distributed (Molden *et al*., 2007).

2.5 Environmental policies

Public irrigation systems had proved to be a significant issue throughout the world. Turral (1995) explained several needs for transferring the cost of irrigation to users due to the fact that most of the international aid and public spending in developing countries are intended for agricultural irrigation. Water charges in most of developing countries have been much lower than those costs required for operations and maintenance (World Bank, 1995).

Implementation of policies and applying reforms proved to be a risky process in MENA countries (Middle East- North African countries), the reason being the weak individual political economy in the applied policies (Kunigk, 1999). In general, for a better management for the scarce water resources, Briscoe (1996), concluded in his study concerning water as an economic good that the economic development and environmental sustainability start with considering water as a scarce resource besides managing scarcity using economic principles as tools. As for irrigation, the largest consumer of water, it needed to be managed with economic consideration in mind. In addition to the scarcity of water as a constraint for the economic growth, another constraint is water pollution. This is considered as a public good (bad) needing an intervention from authorities to abate pollution, to stabilize behaviours and attain an optimal level of environmental sustainability. The effects of openness, trade liberalization, globalization and population growth; triggered the need to apply policies to moderate the consequences of growth on the ecosystem and natural

[6] An underground bed or a layer of permeable rock, or a soil that yields water.

resources. Observers noticed the relation between per capita income and pollution; several instruments can be used for pollution abatement such as taxes.

Grossman and Krueger (1996, p. 120) pointed at the environmental policies *"if environmental improvements are mediated by changes in government policy, then growth and development cannot be a substitute for environmental policy"*, the pollution abatement must be forced and monitored, concerning the inequality in income and environmental quality, governments' public intervention in this case is to ensure the rights of people using the degraded ecosystem. However, there is the possibility that other policies have an impact on water usage access. Shafik and Bandyopadhyay (1992) explored the effect of open economies on the environmental quality by modelling a relation embodying different indicators of the trade policy, such as total imports and exports as share of the GDP. Their regression results showed the insignificant impacts of the trade policy on the lack of water and sanitation per capita.

2.6 The impact of water withdrawal and water quality on the economic growth

2.6.1 The assessment of the water resources

"The word value, it is to be observed, has two different meanings, and sometimes expresses the utility of some particular object, and sometimes the power of purchasing other goods which the possession of that object conveys. The one may be called "value in use"; the other, "value in exchange." The things which have the greatest value in use have frequently little or no value in exchange; and, on the contrary, those which have the greatest value in exchange have frequently little or no value in use. Nothing is more useful than water: but it will purchase scarce anything; scarce anything can be had in exchange for it. A diamond, on the contrary, has scarce any value in use; but a very great quantity of other goods may frequently be had in exchange for it" (Adam smith, The Wealth of Nations, 1776, Book I, chapter 4)[7].

[7] Chapter 4: Of the Origin and Use of Money, Paragraph I.4.13, found online http://www.econlib.org/library/Smith/smWN1.html#anchor_nn84 (Accessed January, 2011).

Starting from Adam Smith, it is more useful to consider water as a good that has a value and a price. The identification of water as an economic good is an important beginning before modelling the contribution of water on the economic growth (Barbier, 2004). Every commodity has an economic value when people are willing to pay to get it. Water is essential for life people cannot survive without consuming it. After the Dublin conference (1992) it becomes accepted to consider water as an economic good. Table (2.2) contains the four principles of the conference. At a later conference, the Rio conference in 1992 held by the UN for environment and development it became even clearer that water management should be treated economically. In general, global water resources and consumption have been quantified comprehensively based on statistical information (e.g., Shiklomanov and Balonishnikova, 2003). At the same time different authors (Arnell, 1999; Alcamo *et al*., 2000; Vörösmarty *et al*.,2000; Döll and Siebert, 2002) introduced hydrological models on a macro scale level to quantify water. There are three interaction factors that contribute to water assessment: the value of water, the user's cost of water, and the opportunity cost of water as a resource (Briscoe, 1996) see figure (2.2) that illustrate the cost of water if under-priced.

The first aspect of *Integrated Water Resources Management Organization* states that water is not divisible into different kinds, whether it is groundwater at some stage, surface water, and rainfall in the other stages they all remain the same water and different sources are interdependent on each other. The widely known measure of the aggregate fresh water is provided by work for FAO-AQUASTAT conducted by Faurés *et al*. (2000) that define the country's aggregate fresh water as the total renewable water resources. This is defined as the total surface runoff on an annual basis, ground water as aquifers recharge through infiltration added to surface inflows from other countries. Water use is divided into two kinds by the hydrologists (Gleick, 2002), one kind is the water withdrawal which is the water extracted or provided by fresh water resource for direct human activities, and the second kind is water consumption that is obtained from the source but can be lost towards the sea, or can be useless due to contamination and cannot be reused or subjected to treatment and recycling after human use. The idea behind developing the water poverty index (Sullivan, 2002) is to create an assessment system in order to monitor the places that are in need of water and provide the required water for these places in order to achieve the required development with the population growth.

Falkenmark and Lindh (1974) were the first to introduce the approach of integrating the physical assessment of water with the water consumption due to population density. Attempts have been done to model the physical assessments of water with relevant social factors by Ohlsson (1998) who tried to link the available renewable water with the adaptive capacity as a water stress- water scarcity index similar to the UNDP Human development index. In 1996, the FAO used the water utilization intensity as an indication of aquifers depletion and when it is over 100%, then aquifers are depleting faster than the recharge rate and in some cases pollution also restricts the usage of some renewable resources. In either case water becomes a constraint on production. A water poverty index terminology introduced by Sullivan (2000), facilitated the opportunity to model water demand that is consistent with the improvement of water management. Different ratios illustrated the degree of interaction between humans and the sustainability of the water resources plus the local water stress index (Vörösmarty *et al.*, 2000). In general, hydrologists usually represent the water stress and scarcity as water availability per person (cubic meters per person per year) or as relative water demand (the ratio of water withdrawals to total fresh water resources per year); Vörösmarty *et al.* (2000) considered the water stress values (a standard assessment in hydrology) for a country between 0.2 and 0.4 to indicate medium to high water stress and values greater than 0.4 reflect conditions of severe water limitation (Cosgrove and Rijsberman, 2000; Vörösmarty *et al.*, 2000).

According to (Savenije and Van der Zaag, 2002) water pricing is an instrument to achieve financial sustainability. If water is for free, then the water provider does not receive sufficient payment for its services, the value of water is the maximum amount that users are willing to pay for the using of the resource (Briscoe, 1996). So, in order to attain future economic growth accompanied with social development, it is necessary to consider water as a production factor in economic development. In general, we cannot exclude the fact that climate, the bio physical and geographic means play a role in availability of water as a renewable resource.

Table 2.2: Dublin principles

The Four Dublin Principles
1. Water is a finite, vulnerable and essential resource which should be managed in an integrated manner. 2. Water resources development and management should be based on a participatory approach, involving all relevant stakeholders. 3. Women play a central role in the provision, management and safe guarding of water. 4. Water has an economic value and should be recognized as an economic good, taking into account affordability and equity criteria.
Source: ICWE, 1992

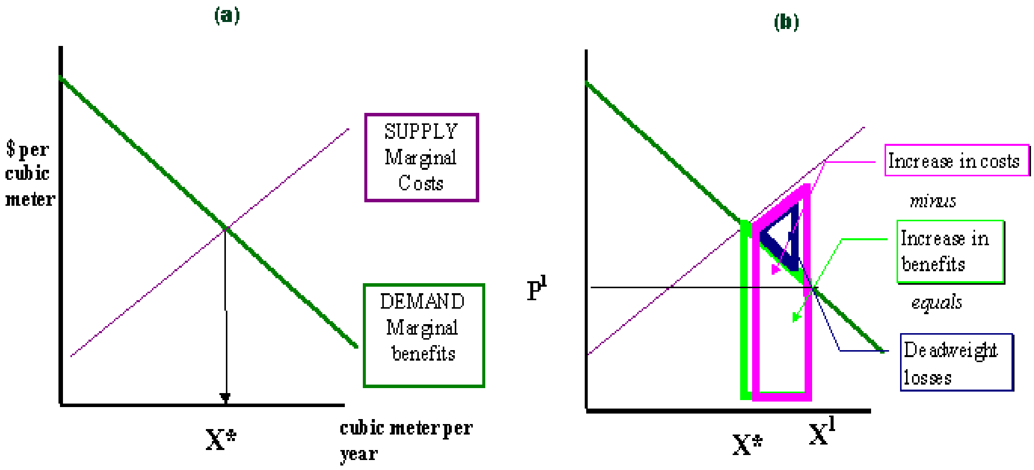

Figure 2.2: Optimal consumption and "deadweight losses" if water is under-priced. (Source: The figure is provided from two sources (Perry *et al*., 1997 and Briscoe, 1996)

Considering water as an economic good subject to congestion, like any other good it has a value, i.e. the user of water is willing to pay for it. Consumers will use water as long as benefits exceed the costs and up to the point at which marginal benefits equal marginal costs. Figure (2.2) reflects this by the value of the optimal consumption X*. Figure (b) illustrated that if a consumer is charged a price P^1, which is different from the marginal cost of supply, then the consumer will consume X^1. The increase in costs (the area under the cost curve) exceeds the increase in benefits (the area under the benefit curve) and there is a corresponding loss of net benefits known as the deadweight loss.

2.6.2 Determinants of economic growth

After World War II, the main interests for policy makers and economists were the economic growth, economic competitiveness and to an extent a political role in the world. Analysts in their part created and modelled a lot of growth models focusing on the technology factors required for a long – run growth, starting with the neo classical growth model (Solow, 1956) which introduced technology into the economic growth. This increased labour productivity and led to the conclusion that the exogenous technical advancements play a critical part in economic growth; Romer (1986) modelled long – run growth with endogenous technical change. Lucas (1988) and Rebelo (1991) adopted the endogenous growth models of technology contribution. However, Parente (2001) considered these models as describing the accumulation of intangible capital and not useful theories of economic development due to an inability to account for several key development facts.

Several attempts have tried to integrate the environmental natural resources in modelling economic growth and to integrate innovation factors with the scarcity of natural resources. The core of the interest here was how to combine unlimited economic growth with a scarcity of the natural resources. Smulders (1995) proposed criteria for modelling to show how innovation facilitates the merger of economic growth with environmental preservation. Nevertheless, the present interaction between growth and environmental scarcity (Homer-Dixon, 1995) revealed the poor economic growth of countries rich in environmental resources (Sachs and Warner, 1995), this is known as the resource curse. That is also tested by (Pack, 1994) who supports the endogenous growth theory in explaining the factors that contribute to technological progress.

The previous literature which modelled the economic growth linked to the environment neglected the fact of waste accumulation and the irreversibility of the damage taking place in the environment and the ecosystem (Smulders, 1999). Smulders added that, the weak part in these models is their inefficiency in testing the short and the long run effect of economic growth on the environment. Ignoring the depletion of the natural resources in modelling economic growth contributed to the failure of the water development projects.

To model the role of water and its effect on the economic growth, we need to specify the kind of economic growth, whether this growth is endogenous or exogenous. Here, our study is focusing on endogenous growth. Usually the required environmental policies and the different sustainability and ecological theories have to be considered with modelling economic growth (Ciccone and Jarocinski, 2008). The Environmental Kuznets Curve (EKC) hypothesis illustrated the relation between resource scarcity and the economic growth, Kuznets curve explains how the pollution is changing with income levels, it reflects how pollution increases with income till the point it started to decline as income rises more. In modelling the economic growth, the raw materials used are at best stable; therefore, the main catalyst for the growth is the innovation and technology (Romer, 1990).

Several studies tried to explore the impact of water on the income. Some studies found no relationship between income and water withdrawal (Gleick, 2003), whereas, Rock (1998) conducted a panel data analysis to explore the effect of the water withdrawal in the USA and registered the presence of an inverted U shape curve for a relationship between water use with exogenous income per capita. Barbier (2004) modelled a relationship between the endogenous economic growth and the water scarcity, using the average annual water withdrawal (km^3/year) to the annual renewable water resources as a measure of fresh water utilization. Considering water as a non-excludable resource subject to congestion, then there are two situations here to be taken into consideration. First, the situation, if the water is not absolutely scarce in the economy, then there must be an inverted U relation between the economic growth and water utilization for a broad number of countries. If the constraint is present and the water is scarce, then if a high amount of output is allocated to provide water, then the excess of allocating inputs would exceed the economic gain, therefore the per capita income and the consumption both would decrease.

2.7 Methodology

Our main interest in this chapter is to explore the effect of water utilization and the water quality on the economic growth and GDP itself, across countries. In this section we analyse the role of the ratio of water utilization and water quality in endogenous economic growth. Where water is expressed in the growth model as a ratio of water utilization that stands as a proxy for water scarcity, and as water quality it stands as a proxy for the value of waste water treatment.

2.7.1. Preliminary description of the model

The concept of water utilization intensity is introduced by the United Nations Food and Agriculture Organization to classify areas that are able to be subjected to water shortage in the future (FAO, 1996; Sullivan, 2002). The ratio of water utilization that express the scarcity of water is used by Berbier (2004) as an indicator of relative water demand and as a conceptual indicator for the amount of water utilized with respect to the available water resources in the economy. The ratio of water utilization is calculated as:

$$\rho = \frac{\textit{water withdrawal per capita}}{\textit{renewable water resources per capita}} \tag{2.1}$$

The pollution is represented here by BOD[8] (biological oxygen demand), the reasons are many for using this indicator. One of these reasons is the availability of credible data that is obtained from the World Bank database. Another reason is the popularity of this indicator in much of the literature that is concerned with water pollution (Crapanzano *et al.*, 2005; Barua and Hubacek, 2008). The BOD is used as an assessment of the damage caused by water pollution, the costs of treatment of water in general is contributed to all the economic sectors.

[8]Biochemical oxygen demand (B.O.D.) is the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in water sample at certain temperature over a specific time period. The BOD value is most commonly expressed in milligrams of oxygen consumed per litre of sample during 5 days of incubation at 20 °C and is often used as a robust surrogate of the degree of organic pollution of water. BOD used as a gauge of the effectiveness of wastewater treatment plants. It is listed as a conventional pollutant in the U.S. Clean Water Act. (Source: Sawyer *et al*. 2003).

However, it reflects only the organic pollution excluding the chemical and the thermal causes of pollution (Crapanzano *et al*., 2005). The organic water pollutant (BOD) emission here is taken as (kg per day).

Generally, water quality here stands as a proxy for the value of waste water treatment, in other words, the value of environmental quality that Briscoe (1996, p.185) pointed at as an expression of the value of environmental quality. Additionally, we added a water pollution variable to reflect the waste accumulation and the irreversibility of the damage taking place in the environment and the ecosystem (Smulders, 1999). Specifically we argue that pollution is bad for growth. Water is a factor of production, water pollution impacts adversely on the quality of this input and will, we argue, reduce both growth and GDP itself. Also, much of previous literature of the water and the economic growth neglected the explanatory variables for pollution, thus also ignoring the depletion of the natural resources during modelling of economic growth models and contributing to the failure of the water development projects and whose effect with growth is the main dimensions of the EKC. Moreover, Mohtadi (1996) used in modelling a long- run endogenous growth under optimal policy designs, the environment as a factor of production into the utility and the production functions, to prove that the optimal growth of any country is directly affected by environmental policies and regulations.

To set up the models, following the previous literature, the ratio of water utilization ρ (Barbier, 2004) and BOD as an indicator of water quality (Barua and Hubacek, 2008), are used. Both are included in linear and in quadratic form. Thus, the relationship between growth, ρ and BOD can be written as:

$$Growth_{it} = \beta_0 + \beta_1 \rho_{it} + \beta_2 \rho_{it}^2 + \beta_3 BOD_{it} + \beta_4 BOD_{it}^2 + \varepsilon_{it} \qquad (2.2)$$

Where *i* stand for country *i* at time *t*, ε is a white noise error term of the regression.

This format is consistent with that in the literature as discussed above. The analysis of growth contains a wide literature that analysed growth for different purposes. The explanatory variables here are chosen to increase robustness of the analysis. The variables used are based on the literature and are chosen for the availability of credible data that covers a sufficiently long period of time (1960- 2009) and for a great pool of countries that represent different continents and income per capita. Several elements of the literatures (for example, Sala-I-Martin 1999; Levine and Renelt, 1992) explored the variables that are important determinants of growth. The vital goal here is using the most accepted variables in literature. The variables that affect growth across countries are many. As we are examining the effect on growth, we add explanatory variables to our equation that are widely used in previous literature as explanatory variables affecting growth and thus cannot be excluded from our considerations. These variables are expressed as a matrix **X** in the following equation:

$$Growth_{it} = \beta_0 + \beta_1 \rho_{it} + \beta_2 \rho_{it}^{\ 2} + \beta_3 BOD_{it} + \beta_4 BOD_{it}^{\ 2} + \beta_5 \mathbf{X}_{it} + \varepsilon_{it} \tag{2.3}$$

As previously mentioned, we need to test our model with a framework that includes the explanatory variables that stand for the impact on the growth in the individual country. $\mathbf{X_{it}}$ includes GDP per capita, the scholar primary enrolment, the scholar secondary enrolment. The first and the second school-enrolment rates variables are used as proxies for human capital, the primary school enrolment rate and the secondary school enrolment rate in the original year to represent the initial stock of capitals used by (Barro,1991; Barbier, 2004; Sala-I-Martin, 1999; Temple, 1999), school enrolments are used here as conceptual indicators to proxy the impact of human capital on growth.

We cannot examine growth without incorporating the impact of governance factors including the political situation in the individual country. As for the political and the civil liberties, the higher the democracy in the society, the greater is the influence of the interest groups that focused on the environmental protection and sustainability. Democracy and good governance may, e.g. act as a stimulus to innovation and investment, both domestic and FDI (Foreign direct investment), thus stimulating growth. The indicators that reflect the political influence are an index of political rights that measure the rights for free elections and the rights for the existence of different political parties as well as the decentralization of the official power. Hence, we choose the variables corruption[9] and political rights index. The Political rights index for the time period (1972-2008) is taken from the Freedom House database last updated 2008; the corruption indicator is obtained from The International Country Risk Guide (ICRG) database for the period (1984-2009). This indicator is used as an assessment of corruption within the political system. Hence, we choose the variables corruption and political rights index to study their significance in our model.

In exploring the economic policy and environmental quality across countries, Shafik and Bandyopadhyay (1992) used the aggregate rates of investment in their model as a share of GDP, for the fact that most of the open economies are characterized by specialization. They also argue that an open economy in higher income countries focuses on capital intensive, and consequently more pollution intensive activities, whereas, the economy in low income countries is more concentrated on labour intensive and consequently less polluting activities. At the same time openness and competition tend to increase the investment in innovation and technology and thus stimulate growth and GDP. In our analysis we use the trade as a percentage of GDP to indicate the openness and as a proxy for the rate of investments.

The explanatory variables include those which may impact on growth and those which moderate the impact of water shortage and quality on growth. The latter is our main focus and hence dictates this approach, although of course the primary impact of a human capital variable, e.g., will be via its traditional impact on growth. We add the Gini index[10] to the model to represent the effect of inequality on the allocation of the natural resources and its effect on growth. The interaction between human and the environment is a crucial part of sustainability theory (WCED – CMED, 1987). At this time, the inequalities in income increase the gap in the society that dominates the relationship between the humans and the environment. Gylfason and Zoega (2002)

[9] This is an assessment of corruption within the political system. Such corruption is a threat to foreign investment for several reasons: it distorts the economic and financial environment; it reduces the efficiency of government and business by enabling people to assume positions of power through patronage rather than ability; and, last but not least, introduces an inherent instability into the political process.(Source: International Country Risk Guide Methodology).

[10] Gini index measures the extent to which the distribution of income (or, in some cases, consumption expenditure) among individuals or households within an economy deviates from a perfectly equal distribution. Thus a Gini index of 0 represents perfect equality, while an index of 100 implies perfect inequality (definition given by the World Bank).

demonstrated that when the distribution of the natural resources proved to be unequal than the distribution of wealth, i.e. inequality in the distribution of income, distribution of education or land is connected to the contribution and share of the natural resource in the national income. In other words inequality in income reflects the inequality in the distribution of natural resources. Moreover different parts of the literature shed light on the environmental quality and inequality, Boyce (1994) recorded the effects of power inequalities between winners and losers with respect to the pollution level. Additionally, Kuznets (1955) introduced an inverted U shape curve for the relationship between a measure of inequality in the distribution and the level of income. In our case we concerned that resource inequality limits the impact of aggregate resources, with specific respect to water and water quality on growth.

Inflation is added to the model because most of the literature links inflation negatively to growth. Here too inflation is linked to food prices and food prices to water availability. Food and water are of central importance in every society and are directly related to the availability of the water resources, weather in irrigation, canning, manufacturing, transporting … etc. Of course there are potential endogeneity problems with including inflation, particularly with respect to growth as the left hand side variable. However, as long as we are modelling growth, we cannot disregard the potential impact of inflation. The variable may also be linked to population increase and the impact of water on food prices.

Population growth adds a demand for the water resources, hence may again limit the impact of available water on economic growth, and is included in the analysis. The modelling of the effect of water utilization on growth is dealing with water as an economic input and as a public good. The more open, democratic and developed the society, the more efficient may be policies and institutions in managing the natural resource and in facilitating growth per se.

2.7.2 Data and descriptive statistics

The details on the data used are summarized in Table 2.3. The water data used is from the FAO- AQUASTAT (2010) update of the renewable water resources and the total water withdrawal per capita. We constructed a scheme to explain the total renewable water resources content, illustrated in figure (2.3). Previous studies like (Barbier, 2004) used the Gleick databases 1999 and 2006. The constraint in using Gleick's database alone is due to availability of only one year data not a series of years or times series data, Gleick in his database used the AQUASTAT database as a source for some data. Moreover, the units of evaluation of water resources and withdrawal are the same, for these reasons we use the data from the AQUASTAT database supported by Gleick's water databases (Gleick, 1998 and Gleick, 1999). The reason for this is to create a higher credibility by getting more accredited data. In addition to the support of the database of the Earth trend for some missing data, some of the missing water withdrawal per capita data are calculated based on the AQUASTAT database. The calculations are done by dividing the total water withdrawal by the total population. The annual fresh water withdrawal obtained by the AQUASTAT is in units of 10^9 cubic meter/ year per capita.

The analysis is based on monitoring the effect of water utilization per capita and the water quality (BOD) on the economic growth process, as well as the level of GDP, across countries, using a panel analysis for 177 countries. The countries are listed in (Table 2.IV, Appendix 2.IV). The calculations of the ratio of water utilization are obtained by applying the definition given in equation (2.1) that is used by Barbier. This is applied by dividing the annual water withdrawal per capita for the individual country by the annual renewable water resources per capita for that country. The definitions of water terminology are included in Appendix 2.I as they are introduced by the AQUASTAT.

We based inflation on the GDP deflator due to the availability of accredited data by the World Bank development indicators database. The remaining variables are the GDP per capita (constant 2000 US$) and population growth (annual %) are obtained from the World Bank development indicators database.

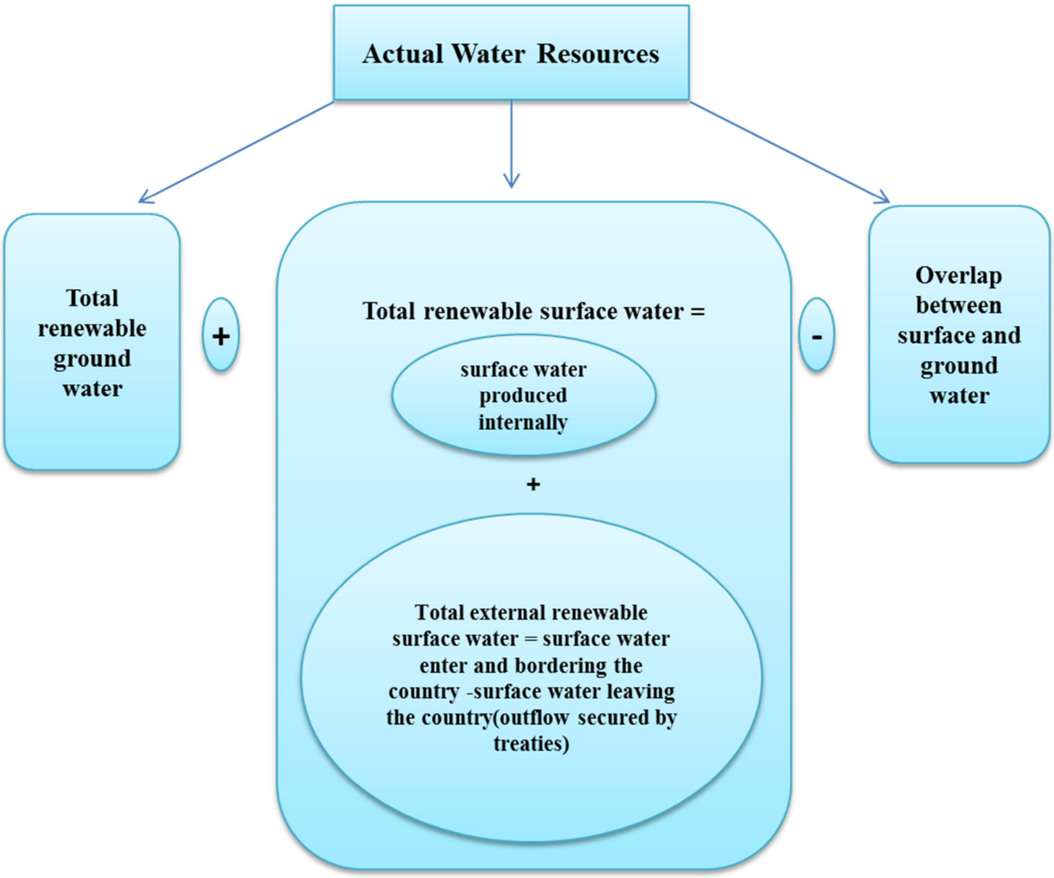

Figure 2.3: The Total Actual Water Resources

To specify if the country under analysis is a developing country we used the dummy variable coded 1 and zero for the developed ones. These categorizations of the countries are made based on the categorization of the UN database. Tables (2.3) and (2.4), contain the definitions and the descriptive statistics of the explanatory variables. Variables that have small numbers of actual observations are interpolated using STATA, the interpolation program is accompanied in Appendix 2.III. The variables we are interpolating are ones which change steadily over time, rather than ones which are dominated by stochastic shocks and hence the interpolations are likely to be reasonably accurate.

Table 2.3: Data description and sources

Variable in model	The source of data
Growth per capita	Gdp per capita (constant 2000$) World Bank Development Indicators data base
Trade as percentage of GDP	World Bank Development Indicators data base
Population growth	The percentage of population growth- WB Development Indicators data base
Inflation	As deflator of GDP- W.B Development Indicators data base
Scholar primary enrolment	As a % net, World Bank Development Indicators data base
School secondary enrolment	As a % net, World bank Development Indicators data base
Gini index	World Bank Development Indicators data base
BOD	Kg per day- World bank Development Indicators data base
Corruption	The International Country Risk Guide (ICRG)
Political rights index	the Freedom House database last updated 2008[11]
Annual fresh water resources	Annual fresh water resources are explained in figure (2.3)
Total water withdrawal	AQUASTAT database 2011

[11] The Political Rights index measures the degree of freedom in the electoral process, political pluralism and participation, and functioning of government. Numerically, Freedom House rates political rights on a scale of 1 to 7, with 1 representing the most free and 7 representing the least free. A rating of 1 indicates free and fair elections, political competition, and autonomy for all citizens, including minority groups. A rating of 2 indicates that a country is less free-there may be some corruption, violence, political discrimination against minorities, and military influence on politics. These same factors play a progressively larger role in countries with a ranking of 3, 4, or 5-citizens of these countries typically experience some political rights (e.g. freedom to organize somewhat controversial groups, reasonably free referenda) along with more damaging influences (e.g. civil war, heavy military involvement, one-party dominance). Countries and territories with political rights rated 6 are ruled by military juntas, one-party dictatorships, religious hierarchies, or autocrats. There may be a few local elections or some minority representation. For countries with a rating of 7, political rights are basically nonexistent due to extremely oppresive regimes, civil war, extreme violence or warlord rule. (Source: Freedom House. 2008).

Table 2.4: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
year	8850	1984.5	14.43169	1960	2009
Dummy variable	8850	0.7118	0.45292	0	1
Population growth	8760	1.8828	1.5421	-8.505	17.74
Trade as % of Gdp	6731	73.4019	43.656	0.3088	438.09
Gdp per capita	6822	5254.212	8042.217	0.0213	59182.83
Gini index	640	41.88461	10.22042	19.01	74.33
Gini (Stata interpolation)	7450	40.94216	13.6219	18.0016	79.5176
Annual water resources p.c.	1712	29348.76	79098.76	0	928962
Annual water resources p.c.(Stata interpolation)	8400	40662.82	103864.7	0	934184.6
Withdrawal water p.c.	804	584.8251	710.532	11.55	9112
Withdrawal water p.c.(Stata interpolation)	8850	533.3876	699.896	11.9159	6424.366
Ratio of water utilization (ρ)	8350	0.4226	2.017465	2.44E-05	19.819
Bod	940	0.2229	0.6818	0.000132	9.4288
Bod (Stata interpolation)	4950	0.2258	0.7168	0.000109	7.1648
Corruption	3306	3.024816	1.369	0	6.166
Political right index	5711	3.972334	2.238	1	7
inflation	6795	42.3905	492.5917	-33.532	26762.02
Scholar 1ry enrolment	3012	82.47538	19.316	9.13977	100
sch1ry(Stata interpolation)	8550	97.4400	6.7882	24.533	100.008
Scholar 2ry enrolment	1231	63.2566	27.1281	1.237	99.764
Sch2ry(Stata interpolation)	7750	98.4772	2.4578	74.577	99.4303

2.7.3 Estimation Framework

The main goal is to explore the effect of the ratio of water utilization together with water quality in the endogenous economic growth and also on endogenous GDP per capita models using equation (2.3), with $\mathbf{Y}_{it}$ a generic term on the left hand side.

$$\mathbf{Y}_{it} = \beta_0 + \beta_1 \rho_{it} + \beta_2 \rho_{it}^{\,2} + \beta_3 BOD_{it} + \beta_4 BOD_{it}^{\,2} + \beta_5 \mathbf{X}_{it} + \varepsilon_{it} \tag{2.3}$$

Where $\mathbf{Y}_{it}$ on the left hand side of the equation stands for: the GDP per capita, the annual growth and the rate of five years growth. The analysis is done by using a panel analysis with pooled ordinary least squares constant coefficients models, fixed effects model, and random effects model.

The analysis is done on three different independent variables, so that each group embodied three different sets of panels,

- Panels for the effect of water utilization and BOD on the per capita GDP at year t, GDP per capita is of course not growth, but represents the prosperity of a country. Now it is possible that the impact of variables such as water and pollution on GDP per capita may be different from growth. GDP per capita depends upon available resources, how efficiently they are used. Growth reflects any increases or/and decreases in resources, and may reflect increases in their efficiency of use and any growth of knowledge.
- The second sets of panels are for the percentage of growth or the annual growth.
- To see the effect on economic growth of ρ and BOD on a longer period we build on Barbier's model (2004) who used a range of five year growth rate with the rate of water utilization. In taking the rate of five year growth, calculations are done by taking the percentage of growth from year t till year (t+5) and regressed with ρ and BOD at year t. That is in addition to the possibility of cross sectional heterogeneity in parameters taking into considerations that the data is related to different countries with different dimensions of data. In the context of equations (2.2) and (2.3) which are introduced in the previous section, we used the five years as the basis for analysis for three reasons. Firstly to see the effect at a longer period of time period, but not too long due to different factors like climate, socio- economic, political and institutional reforms that can affect the performance of the economy in the long run. The other reason is to compare our analysis with previous literature (Barbier, 2004) for statistical purposes and to base an objective mechanism in our analysis. Also there is an argument that it reduces the fluctuations in the business cycle.

We used a cross section times series unbalanced panel ($T_i \neq T$ for some i) for 177 countries covering the periods from 1960 until 2009, these models are referred to as cross-sectional time-series models. The attractiveness of the panel data analysis is found in the high number of observations, and more degrees of freedom due to more observations, for they have time-series of observations for an individual entity rather than an aggregate level or a single observation. They allow also solving the problem of omitted variables heterogeneity. They specifically control for individual specific, time-invariant' characteristics and the unobserved heterogeneity, whose presence may lead to biased estimators in the standard OLS estimator. We used the fixed effects and the random effects for each individual panel[12]. The fixed effects is used to study the impact of variables that vary over time, for the fixed effects we explore the relationship between the dependent and the explanatory variables, and omit the effects of time invariant characteristics from the explanatory variables (Hausman and Taylor, 1981). If the fixed effects are not correlated with the other explanatory variables and the error terms are correlated for the same country, then we need to use the random effects.

The main difference between the random and the fixed effects is the freedom to analyse the time invariant variables. The fixed effects is picking up as significant difference between countries *"the crucial distinction between fixed and random effects is whether the unobserved individual effect embodies elements that are correlated with the regressors in the model, not whether these effects are stochastic or not"* (Green, 2008, p.183). To distinguish between the two effects we apply the Hausman test after the two models. If the Hausman test (and the chi-square value) indicates that we will reject the null hypothesis ($P<0.05$) for the random effects model we must go with the fixed effects model.

We estimate our models using a robust estimate for the standard errors to control for the hetreoskedasticity[13]. We run a modified Wald statistic for group wise heteroskedasticity in the residuals of a fixed effect regression model. The null hypotheses of Wald test is rejected (Prob>chi2 = 0.0000), indicating the presence of heteroskedacticity. To overcome this issue we used robust standard errors relying on the advice of Stock and Watson (2006, p.166) that, when using the standard IV estimator: *"Economic theory rarely gives any reason to believe that the errors are homoskedastic. It therefore is prudent to assume that the errors might be heteroskedastic unless you have compelling reasons to believe otherwise. [...] If the*

[12] We are discussing in details the mechanism of the fixed and the random effects in chapter 3.

[13] We run the heteroskedacticity test after the fixed effect model using a modified Wald statistic for group wise heteroskedasticity and assuming homoskedasticity. This technique is developed by STATA group building upon Greene (2000, p.598). The hypothesis is that sigma (i)^2 = sigma^2 for i=1,N_g, where N_g is the number of cross-sectional units. The resulting test statistic is distributed Chi-squared (N_g) under the null hypothesis of homoskedasticity.

homoskedasticity-only and heteroskedasticity-robust standard errors are the same, nothing is lost by using the heteroskedasticity-robust standard errors; if they differ, however, then you should use the more reliable ones that allow for heteroskedasticity. The simplest thing, then, is always to use the heteroskedasticity-robust standard errors". We use robust standard errors to control for mild violation of the distribution assumption that the variance equals the mean (Cameron and Trivedi, 2009).

The correlation coefficient test indicates a presence of correlation relation between the x and the x^2 (i.e. the two quadratic form variables) in the model, but the mean variance inflation factor[14] which is included in the tables of regressions gave accepted numbers for the variables (the mean variance inflation factor for each except for the x and the x^2 variables), but since x^2 is an interaction term of itself; x and x^2 will be fairly collinear.

Much of the previous literature that modelled the effect of pollution on growth used the exogenous growth effect in the model that affects the endogenous pollution, here in our model we are exploring the effect of water quality that is expressed by BOD as an exogenous variable in the endogenous growth model. There is a causality effect between growth and BOD, it is almost a stylized fact that growth causes pollution, this can interfere in the regression results and also results in endogeneity that causes a biased estimator. Some of the regressors are correlated with the error term, $\text{cov}(x_{ik}, u_i) \neq 0$. In this case, the regression analysis needs further treatment to deal with the causality effect of the regressors on the dependent variable.

[14]Variance inflation factor (VIF) quantifies the severity of multicollinearity in an ordinary least squares regression analysis. It provides an index that measures how much the variance (the square of the estimate's standard deviation) of an estimated regression coefficient is increased because of collinearity.

We can use the instrumental variable technique in the fixed effects model. All results are reported in column 3 in tables 2.5 through to table 2.7. This instrumented variable is an exogenous variable that is correlated with the endogenous variable but not with the error terms cov (IV_{it}, u_i) =0.

The fixed effects cannot estimate the time invariant estimators, for that using the instrumental variable method is a proper method, the main issue here in our regression that we need to take into consideration is that we are using environmental variables and socioeconomic variables. The finding of external instrumental variables is thus a challenging task[15]. The variables that are chosen affect the quality of the environment through the effect on the GHGs (greenhouse gasses). For this task that we have to identify the aspects (substances and materials produced by businesses' activities or products or services that can interact with the environment) in addition to their environmental impacts and that is defined by ISO- (ISO 14001:2004) for environmental management system- as '*any change in the environment whether adverse or beneficial, wholly or partially resulting from an organisation's activities, products, or services*' that causes harm whether directly or indirectly to the quality of the environment. In the case of water quality the aspects can be the discharges of wastes in water and the impact is the damage to the aquatic system.

[15] The variables used for instrumentation are Methane emissions in energy sector (thousand metric tons of CO_2 equivalent), SF_6 (Sulfur hexafluoride) gas emissions (thousand metric tons of CO_2 equivalent), they are chosen for their dramatic effect on the water quality and due to the credibility of the data. (source: World Bank development report)

Dependent variable is BOD (for year 20001-2009)	
Constant	0.198***
	(7.96)
Methane emissions in energy sector	0.406***
	(3.40)
SF_6 gas emissions	0.375**
	(2.71)
N	688
R-sq	0.076
adj. R-sq	0.073
F statistics	28.24***
rmse	0.648

Prob > F - This is the p-value associated with the above F-statistic. It is used in testing the null hypothesis that all of the model coefficients are 0.

We rerun the regression with the instrumental variables and use the Davidson-MacKinnon test to test for the exogeneity after the fixed effect instrumental variable model, the results are included in the regression tables (column 4) in tables 2-5-2.7, the acceptance of the null indicates ($p>0.05$) that are not significant, in other words the endogenous regressors are not affecting the regression results in the FE model and instrumenting BOD is not required[16].

2.7.4 Results

In our analysis, we have some basic steps:

- We run the pooled OLS, fixed effects and random effects to compare between different models, all our regressions are included in the appendix 2.II, these tables are the basic skeleton for a framework that examines the behaviour of the environmental variables that are explored heavily in chapter three.
- We reported the goodness of fit, the root mean square errors and Hausman test to compare within models with same dependent variable. All these tests are included in the tables of the regression results (tables 2.5, 2.6 and 2.7).
- Our aim is to see the estimation results of ρ in its linear and quadratic form ($\rho+\rho^2$) and the effect of BOD as ($BOD+BOD^2$) on GDP per capita, percentages of growth and the rate of five years growth.
- We are going to discuss the fixed effects results in this chapter (Hausman test). For better illustration of the model we use two specifications, the first specification introduces the effect of our variables of interest within the model (column 1). The second specification introduces the model with the ratio of water utilization ($\rho+\rho^2$) that is present in column 2 in the three tables. The third specification adds both ($\rho+\rho^2$) and water quality ($BOD+BOD^2$) to see the effect for different specifications of growth within the model context (column3-tables 2.5, 2.6 and 2.7). The fourth column of each table is for the

[16] According to the authors of this post estimations (Christopher F Baum, Boston College, USA and Steven Stillman, RAND Corporation, USA) a rejection indicates that the instrumental variables fixed effects estimator should be employed. See Davidson and MacKinnon (1993, p. 237-240) and Wooldridge (2000, p. 483-484).

fixed effect model in column 3, but where BOD is instrumented (we just instrumented BOD, not BOD^2).

- We calculated the turning points[17] of ρ and BOD using the models in column 3 (tables 2.5-2.7), where it represents the peak impact of ρ and BOD in the same FE model.

The goodness of fit values (based on the F-statistics) suggested the rejection of the null hypothesis that all coefficients are zero. It is also clear the significant effect of the ratio of water withdrawal on the GDP per capita, on the annual growth and on the rate of five years growth which results are included in the column (2) of the tables. That expands on the results given by Barbier (2004) who mentioned that the database he used limited his work from using the cross section times series analysis for the relationship between ρ and growth and he pointed out that *"Thus, the following empirical analysis must be considered only a preliminary test of the theoretical model, as the results obtained may arise from the use of our limited cross-country data set. A more robust test of the theory must wait until a better (i.e. pooled cross-sectional and time series) data set becomes available"* Barbier (2004, p.8). For the robustness of our results we rerun the regression excluding the countries that are excluded by Mankiw *et al.* (1992) and these countries are oil producer countries[18], we got the same results with a negligible change in the coefficients of the variables. We also exclude the inflation from our model due to the endogeneity effect between growth and inflation, we also got the same results, for more robustness of the results we replace the inflation by a proxy variable such as the international inflation and we got the same results.

From the regression tables, we run the Davidson-MacKinnon test of exogeneity after the FE model instrumenting BOD. We can see that it accepts the null hypothesis which reflects that the ordinary fixed effects in column 3 of the regression tables is a consistent model. Considering the socio economic variables, the Gini index is

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[17] We calculated the turning pints by using first order differentiation of $\beta_1\rho + \beta_2\rho^2 = 0$ and $\beta_3 BOD + \beta_4 BOD^2 = 0$

[18] Countries are Bahrain, Gabon, Iran, Iraq, Kuwait, Lesotho, Oman, Saudi Arabia, and United Arab Emirates.

significant and negative with GDP per capita (column 3, FE), in the annual growth model (column 3, table 2.6) and in the rate of five years growth model (column 3, table 2.7) which is not surprising, although there is a difference in the coefficient results with different dependent variables, which is also not surprising. Inflation affects the annual growth and the rate of five years growth at the 1% significant levels. An increase in inflation by 1% affects annual growth negatively by 0.01 pecent and the rate of five years growth by 0.07 %. These two variables are additional as our contribution to their effect on growth and were missing in Barbier's model. The negative coefficient indicates the causality runs from inflation to growth.

Proceeding to our variables of primary interest- the environmental variables- it is clear that the preliminary model included in the column (1) in the three tables (tables 2.5, 2.6 and 2.7) gives a significant impact of both variables, of ρ and BOD on growth. But we can see the sign of the coefficient of estimation of ρ has changed between column (1) and the other columns for the annual growth (table 2.6) and the rate of 5 years growth (table 2.7). That can be due to the effect of including the other macroeconomic variables. The results in column (1) of the preliminary model may be considered to give a biased estimator. However, it can also be viewed as giving a total estimator which just focuses on the direct and indirect impact of the environmental variables, ruling out the indirect effects via other variables. Also, we cannot ignore the influence of the geography and the region, in addition to different income levels that are associated with different countries. Additionally, this is a fixed effects model that captures these individual countries effect which can affect the regression results within the context of different models.

The significant effect of the ratio of water utilization is apparent and consistent between the different models in table 2.5 relating to the log of GDP per capita, where the effect shows an inverted U shaped effect on the GDP per capita. BOD on the other hand, is significant at the 1% significant level on the GDP per capita in both its linear and quadratic form (column 3, table 2.5). It appears to have an increasing effect on GDP per capita and then turns at the saturation point (turning point 0.2) where the economy cannot grow anymore, where the operation cost exceeds the benefits and then starts to decrease; this can be due to the effect of an increase in the input and operational costs for the economy.

Turning to the other tables, there is clear evidence for the presence of an inverted U shaped relationship of the effect of the water utilization on growth. Regression results show an interaction between water quality and ratio of utilization in their effect on growth on the long run. Specifically the results show a significant impact of ρ alone at a 5% significant level on annual growth (column 2, table 2.6) and that ρ affects the rate of five years growth at a 1% significant level (column2, table 2.7). This significance disappeared when we added BOD to the model; BOD appears to be significant at the 1% level for GDP per capita (column 3, table 2.5), annual growth (column 3, table 2.6) and the five years growth (column 3, table 2.7). This indicates that the quality of water affects growth more than the quantity in the longer run. That indicates the presence of a U shaped curve in the effect of water quality in long run growth. BOD may well be linked with higher GDP per capita, as rich industrial countries tend to be relatively heavy polluters.

Table 2.5: Regression analysis of water utilization and BOD with Log GDP per capita as a dependent variable

Dependent variable Log GDP per capita				
	FE	FE	FE	FE/IV
	Column(1)	Column(2)	Column(3)	Column(4)
Constant	35.98***	-15.02***	-43.77***	-48.27***
	(17.02)	(5.05)	(15.01)	(8.96)
ρ	-0.956***	0.189*	0.220***	0.221***
	(14.2)	(2.49)	(3.97)	(3.51)
ρ^2	2.262***	-0.419*	-0.548***	-0.557***
	(12.88)	(2.16)	(3.86)	(3.48)
Bod	9.148***		0.472***	0.192
	(21.83)		(5.28)	(0.32)
Bod^2	-0.542***		-0.958***	
	(14.04)		(4.45)	
Gini index		0.705***	1.039***	1.130***
		(22.34)	(29.58)	(7.05)
Inflation		-0.0003	-0.0001	0.001
		(0.60)	(0.08)	(0.86)
Pop growth		0.026***	0.037***	0.044***
		(5.01)	(7.83)	(6.62)
Political rights index		0.02*	0.02***	0.013***
		(2.21)	(5.64)	(3.91)
Corruption		-0.03***	-0.013**	-0.01
		(6.33)	(3.10)	(1.66)
Scholar enrol.1ry		0.003*	0.005***	0.01
		(2.29)	(4.49)	(1.44)
Scholar enrol. 2ry		-0.00471*	0.001	0.004
		(2.37)	(0.49)	(0.79)
Trade as % of gdp		0.00131***	0.001***	0.001**
		(6.2)	(5.22)	(3.2)
Dummy variable		.	.	.
		.	.	.
N	3740	2459	1590	1590
R-sq	0.233***	0.407***	0.687***	0.441***
adj. R-sq	0.213	0.376	0.67	
rmse	0.37	0.142	0.103	
Hausma test	740.34***	146.90***	293.91***	

t statistics in parentheses * p<0.05, ** p<0.01, *** p<0.001. Modified Wald test for groupwise heteroskedasticity in fixed effect regression model (H0: sigma(i)^2 = sigma^2 for all i) is 65937.73*** indicating a heteroskedacticity which is alleviated by using the use the heteroskedasticity-robust standard errors. The mean value of the variance inflation factors of the overall variables in the models is 9.86
The significance of R-sq is based on F-statistics.

Davidson-MacKinnon test of exogeneity: 0.0431282 F(1,1506) P-value = 0.8355

Turning point ρ: 0.20, Turning point BOD: 0.25

Table 2.6: Regression analysis of water utilization and BOD with annual growth as a dependent variable

Dependent variable: Annual growth				
	FE	FE	FE	FE/IV
	Column(1)	Column(2)	Column(3)	Column(4)
Constant	194.5**	-303.5***	-142.3	16.51
	(2.92)	(3.36)	(1.03)	(0.02)
lgdpcp	2.966***	3.965***	4.471***	5.896
	(5.85)	(5.50)	(5.69)	(0.89)
ρ	-6.408***	13.474**	4.383	14.03
	(3.32)	(3.10)	(1.02)	(0.01)
ρ^2	0.167***	-0.340**	-0.111	-0.222
	(3.37)	(2.98)	(1.00)	(0.01)
Bod	-0.247		-1.675***	-2.053
	(1.72)		(5.42)	(0.49)
Bod^2	0.0122		0.337***	
	(1.09)		(4.11)	
Gini index		-0.119**	-0.129***	-0.17
		(3.24)	(3.34)	(1.06)
Inflation		-0.001***	-0.0103***	-0.01**
		(3.49)	(3.41)	(3.00)
Pop growth		-2.120***	-2.111***	-2.55
		(9.53)	(7.90)	(1.87)
Political rights index		-0.0804	-0.037	-0.103
		(0.66)	(0.26)	(0.23)
Corruption		-0.0119	-0.0636	-0.271
		(0.08)	(0.41)	(0.47)
Scholar enrol. 1ry		0.00764	0.0114	-0.0117
		(0.51)	(0.63)	(0.18)
Scholar enrol. 2ry		0.0668	0.0625	-0.124
		(1.22)	(1.17)	(0.32)
Trade as % of gdp		0.0299***	0.0410***	0.0381***
		(3.83)	(4.88)	(4.10)
Dummy variable		.	.	.
		.	.	.
N	2594	1427	1011	1011
R-sq	0.023***	0.152***	0.161***	0.0757***
adj. R-sq	-0.016	0.081	0.089	
rmse	5.228	3.211	2.976	
Hausma test	47.06***	78.20***	72.09***	

t statistics in parentheses * p<0.05, ** p<0.01, *** p<0.001
Modified Wald test for groupwise heteroskedasticity in fixed effect regression model (H0: sigma(i)^2 = sigma^2 for all i) is 3.7e+29*** indicating a heteroskedacticity which is alleviated by using the use the heteroskedasticity-robust standard errors. The mean value of the variance inflation factors of the overall variables in the models is 8.57
The significance of R-sq is based on F-statistics.

Davidson-MacKinnon test of exogeneity: 0.1663 F(1,930) P-value = 0.6835

Turning point ρ: 19.8, Turning point BOD: 2.49

Table 2.7: Regression analysis of water utilization and BOD with rate of five years growth as a dependent variable

Dependent variable: the rate of five years growth				
Variable	FE	FE	FE	FE/IV
	Column(1)	Column(2)	Column(3)	Column(4)
Constant	214.6	-1095.0***	-233.5	-759.3
	(1.26)	(4.64)	(0.77)	(1.13)
lgdpcp	23.20***	26.92***	31.16***	22.34***
	(17.97)	(14.26)	(14.19)	(3.96)
ρ	-11.53*	4.188***	4.72	1.726
	(2.36)	(3.68)	(0.43)	(0.89)
ρ^2	0.338**	-1.024***	-9.813	-0.402
	(2.7)	(3.43)	(0.35)	(0.82)
Bod	-18.81***		-7.496***	-0.367
	(5.25)		(9.94)	(0.11)
Bod^2	8.816**		1.426***	
	(3.21)		(7.64)	
Gini index		-0.330***	-0.439***	-0.285
		(3.44)	(4.08)	(1.77)
Inflation		-0.0014***	-0.069***	-0.032***
		(3.78)	(5.58)	(3.69)
Pop growth		-4.595***	-5.988***	-2.907*
		(7.81)	(8.32)	(2.18)
Political rights index		0.122	0.255	0.541
		(0.38)	(0.71)	(1.02)
Corruption		0.432	0.19	0.643
		(1.16)	(0.46)	(1.01)
Scholar enrol.1ry		0.103**	0.0375	0.101
		(2.61)	(0.81)	(1.44)
Scholar enrol. 2ry		0.426**	0.264	0.354
		(2.97)	(1.84)	(1.03)
Trade as % of gdp		0.068**	0.086***	0.083***
		(3.3)	(3.91)	(3.44)
Dummy variable		.	.	.
		.	.	.
N	2507	1418	1005	1005
R-sq	0.136***	0.291***	0.360***	0.245***
adj. R-sq	0.100	0.232	0.306	
rmse	12.68	8.411	7.571	
Hausma test	276.62***	37.33***	220.51***	

t statistics in parentheses * p<0.05, ** p<0.01, *** p<0.001
Modified Wald test for groupwise heteroskedasticity in fixed effect regression model (H0: sigma(i)^2 = sigma^2 for all i) is 89498.23*** indicating a heteroskedacticity which is alleviated by using the use the heteroskedasticity-robust standard errors.
The mean value of the variance inflation factors of the overall variables in the models is 8.73
The significance of R-sq is based on F-statistics.

Davidson-MacKinnon test of exogeneity: 0.4395 F(1,925) P-value = 0.5075

Turning point ρ: 0.24, Turning point BOD: 2.677

2.8 Conclusion

Our study is to examine the effect of the ratio of water utilization together with the effect of water quality on the endogenous model of economic growth across countries. We conducted panels of 177 countries, using the assessment used by (Barbier, 2004), which is the ratio of water utilization, and we also used BOD as a conceptual indicator of water quality and water pollution. In modelling endogenous growth, we added water quality to the growth model to correct for a weakness in the previous growth models that led to their inefficiencies in testing their impact on short run and long run economic growth. The pollution of water reflects the waste accumulation and the irreversibility of the damage taking place in the environment and the ecosystem. The previous literature that modelled the economic growth with the environment neglected this fact. The concern of our analysis was do these variables impact on growth? Do water utilization and water pollution impact have a dual effect on economic growth? Or, for the latter, does economic growth have a capacity to absorb the accumulation of the pollutants (López, 1994)?

Focusing on the results in column 3 in tables 2.5-2.7 our empirical analysis strongly supports the presence of an inverted U relationship in the effect of water scarcity on the economy in the short and the long run; also there is evidence that the effect of water quality exceeds the effect of water quantity on growth. We have seen the impact of BOD on growth that suggests as long as water quality improves growth increases and vice versa. We have proved support for the hypothesis that water quality and quantity affect the economy. The growth model should not anymore be restricted to socio economic variables, but is affected by the environmental variables as well. This emphasises the interaction between economy and environmental quality and our model substantiates the hypothesis that economic growth can be restricted by environmental quality.

Our results show the effect that as water utilization increases so growth increases until a maximum point, where a scarcity factor becomes relevant and the amount of water resources restrict growth where beyond this point growth starts to decrease (due to exploitation of the renewable water sources) and growth responds by decreasing as well. There is evidence that both water utilization and BOD constrain growth. Water utilization may be managed as an economic sector, but water utilization cannot decrease with the increase of population and industrialization which characterize the world today. Moreover, the water pollution can be mitigated and decreased in the short run by technological advancements, but this is in the short run, as long as humanity are not changing their behaviour and environmental policies are not strict in different regions of the world, water pollution may stay as a persistent issue accompanying human activity.

We believe that the model with just the effect of the water utilization reflects the impact of water quantity on the economy, whereas the model with the BOD together with the water utilization also describes how the quality of water affects the economy and how the pollution affects the deterioration of the natural resource. Water pollution adds a burden to the quality of the withdrawn water and adds more to the cost of production, which has an adverse impact on the growth of the economy. Arguably our results show that quality is more important than the quantity of water. The significance of BOD is important. Given limited water we can only do so much in using that water more efficiently. But BOD is different and offers the hope that by focusing on pollution we can loosen some of the constraints of water on growth. Results are consistent with our expectations that as long as BOD decreases growth on the long run increases.

As we noticed the differences between the different estimators' coefficients can be explained in part by the unobserved heterogeneity which leads to biased estimators that can be explained by the heterogeneity of the country. Nonetheless the differences between the different estimators are a cause for at least thought, if not concern. Thus in the next chapter we will look at this in more detail and propose a possible explanations for what has happened to the environmental variables in the regression, going from OLS to fixed and random effects. Hence we contribute more to the final interpretations of these results in the next chapter, which investigate the effectiveness of the fixed effects in standing for the effect of environmental variables on growth. This reflection on Fe is to explore and speculate in what way are the environmental variables affecting growth and how do they behave in the growth model?

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Appendix 2.I

Definition:
Total Actual Renewable Water Resources (TRWR_actual): The sum of internal renewable water resources (IRWR) and external actual renewable water resources (ERWR_actual). It corresponds to the maximum theoretical yearly amount of water actually available for a country at a given moment. **Unit:** km^3/year or 10^9 m^3/year
Calculation Criteria:
[Water resources: total renewable (actual)] = [Surface water: total renewable (actual)] + [Groundwater: total renewable (actual)] - [Overlap between surface water and groundwater]
Definition:
This is the sum of the internal renewable surface water resources and the total external actual renewable surface water resources. **Unit:** km^3/year or 10^9 m^3/year
Calculation Criteria:
[Surface water: total renewable (actual)] = [Surface water: produced internally] + [Surface water: total external renewable (actual)]
Calculation Criteria:
[Surface water: total external renewable (actual)] = [Surface water: inflow not submitted to treaties] + [Surface water: inflow secured through treaties (actual)] + [Surface water: accounted part of border lakes (actual)] + [Surface water: accounted flow of border rivers (actual)] - [Surface water: outflow secured through treaties]

Source: FAO- AQUASTAT

Appendix 2.II

Table 2.II.1: Table of models of regression of Log GDP per capita with ρ and BOD

Dependent variable: Log GDP per capita						
	Pooled OLS	FE	RE	Pooled OLS	FE	RE
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	7.469***	35.98***	6.694***	-21.56*	-43.77***	-36.78***
	(16.65)	(17.02)	(18.79)	(2.32)	(15.01)	(8.38)
ρ	0.338***	-0.956***	0.724	0.339***	0.220***	-0.199
	(4.28)	(14.20)	(0.95)	(5.26)	(3.97)	(0.43)
ρ^2	-0.0197***	2.262***	-0.0411	-0.0158***	-0.548***	0.01
	(4.98)	(12.88)	(1.08)	(4.84)	(3.86)	(0.39)
Bod	1.852***	9.148***	3.968	1.677***	0.472***	1.674
	(22.17)	(21.83)	(1.51)	(7.85)	(5.28)	(1.61)
Bod^2	-0.313***	-0.542***	-0.158	-0.450***	-0.958***	-0.334
	(22.04)	(14.04)	(0.71)	(4.38)	(4.45)	(1.15)
Gini index				0.847***	1.039***	1.099***
				(3.87)	(29.58)	(10.56)
Inflation				0.0005	-0.000142	0.001
				(0.06)	(0.08)	(1.15)
Pop growth				0.0659*	0.0367***	0.0461**
				(2.41)	(7.83)	(2.88)
Political rights index				-0.181***	0.018***	0.0114
				(9.90)	(5.64)	(1.28)
Corruption				0.400***	-0.0134**	-0.01
				(16.1)	(3.10)	(0.76)
Scholar enrol.1ry				-0.0304***	0.005***	0.004
				(5.27)	(4.49)	(1.85)
Scholar enrol. 2ry				-0.0320**	0.001	0.002
				(3.25)	(0.49)	(0.6)
Trade as % of gdp				0.00482***	0.001***	0.001
				(6.76)	(5.22)	(1.37)
Dummy variable				-0.678***	.	-1.569***
				(8.36)	.	(4.58)
N	3740	3740	3740	1590	1590	1590
R-sq	0.101	0.233		0.586	0.687	
adj. R-sq	0.1	0.213		0.582	0.67	
rmse	1.54	0.37	0.433	1.03	0.103	0.11
Hausma test		740.34***			293.91***	

Table 2.II.2: Table of models of regression of annual growth with ρ and BOD

Dependent variable: Annual Growth						
	Pooled OLS (1)	FE (2)	RE (3)	Pooled OLS (4)	FE (5)	RE (6)
Constant	-1.150	194.5**	-1.855	2.091	-142.3	1.054
	(1.44)	(2.92)	(1.83)	(0.77)	(1.03)	(0.33)
lgdpcp	0.376***	2.966***	0.460***	-0.332*	4.471***	-0.351
	(4.22)	(5.85)	(3.93)	(2.15)	(5.69)	(1.30)
ρ	-0.856*	-6.408***	-0.910*	-0.942**	4.383	-0.836
	(2.32)	(3.32)	(2.56)	(3.08)	(1.02)	(1.33)
ρ^2	0.0461*	0.167***	0.0490**	0.0459**	-0.111	0.0406
	(2.47)	(3.37)	(2.68)	(3.01)	(1.00)	(1.32)
Bod	-0.880*	-0.247	-1.018	-0.323	-1.675***	-0.883
	(2.52)	(1.72)	(1.78)	(0.48)	(5.42)	(0.70)
Bod^2	0.280***	0.122	0.302***	0.323	0.337***	0.626
	(5.41)	(1.09)	(3.38)	(1.15)	(4.11)	(1.20)
Gini index				-0.01	-0.129***	-0.045
				(0.57)	(3.34)	(1.54)
Inflation				-0.0112**	-0.0103***	-0.0103***
				(2.92)	(3.41)	(3.45)
Pop growth				-1.317***	-2.111***	-1.447***
				(7.71)	(7.90)	(5.05)
Political rights index				0.433**	-0.037	0.275
				(3.20)	(0.26)	(0.99)
Corruption				-0.298**	-0.0636	-0.319
				(2.67)	(0.41)	(1.65)
Scholar enrol.1ry				0.007	0.0114	0.0237
				(0.54)	(0.63)	(1.18)
Scholar enrol. 2ry				0.04	0.063	0.047
				(1.66)	(1.17)	(1.64)
Trade as % of gdp				0.0187***	0.0410***	0.0249**
				(6.42)	(4.88)	(3.20)
Dummy variable				-0.706	.	0.371
				(1.66)	.	(0.40)
N	2594	2594	2594	1011	1011	1011
R-sq	0.029	0.023		0.192	0.161	
adj. R-sq	0.027	-0.016		0.181	0.089	
rmse	5.338	5.228	5.268	3.373	2.976	3.086
Hausma test		47.06***			72.09***	

Table 2.II.3: Table of models of regression of rate of five years growth with ρ and BOD

Dependent variable: the rate of 5 years growth						
	Pooled OLS	FE	RE	Pooled OLS	FE	RE
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	-9.634***	214.6	-35.59***	14.79	-233.5	-28.25
	(4.52)	(1.26)	(7.83)	(1.57)	(0.77)	(1.62)
lgdpcp	2.232***	23.20***	5.312***	-0.448	31.16***	1.74
	(9.06)	(17.97)	(10.14)	(0.79)	(14.19)	(1.81)
ρ	-3.200***	-11.53*	-4.309*	-3.853**	4.72	-1.013
	(4.26)	(2.36)	(2.50)	(3.30)	(0.43)	(0.36)
ρ^2	0.173***	0.338**	0.234**	0.186**	-9.813	0.0464
	(4.49)	(2.7)	(2.63)	(3.22)	(0.35)	(0.32)
Bod	-3.826**	-18.81***	-7.505**	-1.74	-7.496***	-2.422
	(3.24)	(5.25)	(2.75)	(0.66)	(9.94)	(0.29)
Bod^2	1.253***	8.816**	1.820***	1.479	1.426***	0.772
	(6.82)	(3.21)	(4.29)	(1.4)	(7.64)	(0.19)
Gini index				-0.0252	-0.439***	-0.190*
				(0.46)	(4.08)	(1.97)
Inflation				-0.0430**	-0.069***	-0.0353***
				(2.69)	(5.58)	(3.88)
Pop growth				-4.259***	-5.988***	-2.821***
				(7.40)	(8.32)	(3.81)
Political rights index				1.788***	0.255	0.897*
				(3.41)	(0.71)	(2.24)
Corruption				-1.607***	0.19	-1.278**
				(3.93)	(0.46)	(3.02)
Scholar enrol.1ry				0.0211	0.0375	0.134**
				(0.59)	(0.81)	(2.61)
Scholar enrol. 2ry				0.0231	0.264	0.168
				(0.27)	(1.84)	(1.14)
Trade as % of gdp				0.079***	0.086***	0.125***
				(8.21)	(3.91)	(6.65)
Dummy variable				-4.250*	.	2.156
				(2.56)	.	(0.67)
N	2507	2507	2507	1005	1005	1005
R-sq	0.084	0.136		0.237	0.360	
adj. R-sq	0.083	0.100		0.226	0.306	
rmse	14.46	12.68	13.34	11.46	7.571	9.139
Hausma test		276.62***			220.51***	

Appendix 2.III

Take var stands for the variable that is under interpolation
The interpolation program used for stata is:

```
generate trend=yr-1959
generate trendsq=trend*trend
scalar uplim=X
scalar lowlim=Y
scalar uplim=uplim-lowlim
generate vart= var -lowlim
generate vlog=log(vart/(uplim- vart))

**replace var=. if var==<0
generate var1=.
generate lvar =log(var)
drop py
scalar kt=0
scalar k1=0
generate var2=.
generate py=.
forvalues i1 = 1(1)177 {
scalar k1=k1+1
scalar sx1=0
scalar k3=0
while k3<50 {
scalar kt=kt+1
scalar k3=k3+1

if var[kt] !=. {
scalar sx1= sx1+1
}
}
if sx1>1  {
drop py
*quietly regress lvar trend if code==k1 & sx1>1
quietly regress varlog trend if code==k1 & sx1>1
predict py, xb
replace var2=py if code==k1 & sx1>1 & var==.
*replace var2=lvar if code==k1 & sx1>1 & var!=.
replace var2= varlog if code==k1 & sx1>1 & var!=.
}
}
*replace var2=exp(var2) if var2 !=.
replace var2=exp(var2) if var2 !=.
replace var2=uplim* var2/(1+ var2)+lowlim
sum var2
generate var2o= var2
regress varlog trend
predict py1, xb
generate var3=exp(py1)
replace var3=uplim* var3/(1+ var3)+lowlim
scalar i1=0
scalar i2=0
forvalues i=1(1)177{
scalar i2=i2+1
forvalues j=1(1)50{
scalar i1=i1+1
```

We have some data on Z (water withdrawal). But some of the data is missing. We wish to construct an expanded series, filling in the missing values. We use regression analysis to get predictions of Z. When we have the actual data we use that when we do not, we use the predicted value. The logit transform is fairly standard when using data which is constrained to lie between values (in this case 0 and 100). If the variable is Z it equals log(Z/(100-Z)). This is then the dependent variable. X and Y below are set at 100 and 0 respectively and its exactly equal to log(Z/(100-Z)). We then regress this in this section on a trend, get a predicted value for this and turn it into a predicted value for Z.

Here we regress varlog [=log(Z/(100-Z))] on a trend, take predicted value and start to construct a variable 'var3'. This eventually is the predicted value for Z from the regression.

Ratio is the average ratio of the actual value for Z, where we have it, to the predicted one. Let us suppose this is 1.1 (i.e. actual Z 10% greater than predicted). We then reduce all predictions by 10%. Now the expanded series for Z equals the actual value when we have it. When we do not, we take the predicted value as we have constructed it.

```
scalar sx1=0
scalar ratio=0
if var[i1] !=. {
scalar sx1=sx1+1
scalar ratio= var[i1]/ var3[i1]+ratio
}
scalar ratio=ratio/sx1
if sx1>0 {
display sx1, ratio
summ var2 var3 if code == i2
quietly replace var2= var3*ratio if code == i2 & var2 ==.
}
}
}
summ var2
```

Appendix 2.IV

Table 2.IV.1: List of 177 countries included in the study

The List of countries included in the study				
Afghanistan	Cote d'Ivoire	Italy	Norway	Tajikistan
Albania	Croatia	Jamaica	Oman	Tanzania
Algeria	Cuba	Japan	Pakistan	Thailand
Angola	Cyprus	Jordan	Panama	Timor-Leste
Antigua and Barbuda	Czech Republic	Kazakhstan	Papua New Guinea	Togo
Argentina	Denmark	Kenya	Paraguay	Trinidad and Tobago
Armenia	Djibouti	Korea, D.R.	Peru	Tunisia
Australia	Dominica	Korea, Rep.	Philippines	Turkey
Austria	Dominican R.	Kuwait	Poland	Turkmenistan
Azerbaijan	Ecuador	Kyrgyz Republic	Portugal	Uganda
Bahrain	Egypt, Arab Rep.	Lao PDR	Puerto Rico	Ukraine
Bangladesh	El Salvador	Latvia	Qatar	United Arab Emirates
Barbados	Equatorial Guinea	Lebanon	Romania	United Kingdom
Belarus	Eritrea	Lesotho	Russian Federation	United States
Belgium	Estonia	Liberia	Rwanda	Uruguay
Belize	Ethiopia	Libya	Sao Tome and	Uzbekistan
Benin	Fiji	Lithuania	Principe	Venezuela, RB
Bhutan	Finland	Luxembourg	Saudi Arabia	Vietnam
Bolivia	France	Macedonia, FYR	Senegal	West Bank and Gaza
Bosnia &Herzegovina	Gabon	Madagascar	Serbia	Yemen, Rep.
Botswana	Gambia	Malawi	Seychelles	Zambia
Brazil	Georgia	Malaysia	Sierra Leone	Zimbabwe
Brunei D.	Germany	Maldives	Singapore	
Bulgaria	Ghana	Mali	Slovak Republic	
Burkina Faso	Greece	Malta	Slovenia	
Burundi	Grenada	Mauritania	Somalia	
Cambodia	Guatemala	Mauritius	South Africa	
Cameroon	Guinea	Mexico		
Canada	Guinea-Bissau	Moldova	Spain	
Cape Verde	Guyana	Mongolia	Sri Lanka	
Central African R.	Haiti	Morocco	St. Lucia	
Chad	Honduras	Mozambique	St. Vincent and the	
Chile	Hungary	Myanmar	Grenadines	
China	Iceland	Namibia	Sudan	
Colombia	India	Nepal	Suriname	
Comoros	Indonesia	Netherlands	Swaziland	
Congo, D. R.	Iran, Islamic R.	New Zealand	Sweden	
Congo, Rep.	Iraq	Nicaragua	Switzerland	
Costa Rica	Ireland	Niger	Syria	
	Israel	Nigeria		

Chapter 3

Reflections on Fixed Effects

3.1 Introduction

In chapter two, we estimated the effect of water utilization and water quality on economic growth, using BOD as a water quality indicator. We used the panel data analysis, panel data is attractive here based on different factors, one of which is the gained precision in estimation, particularly from using the fixed effects estimations that allow for the unobserved individual heterogeneity which potentially correlate with the regressors. We know fixed effects reduces potential bias, or at least that is the literature view. But there are differences in the coefficients in OLS, FE and RE estimators and that gave cause for concern and reflection.

This chapter is a complimentary work in which we endeavour to ascertain and support the regression analysis framework that took place in chapter two. To investigate the difference in the coefficients in the panels of regression in chapter two from fixed and random effects, we reflect on the nature of fixed effects. We argue that this involves an implicit, seldom stated and rarely tested assumption that the impact of the country mean of a variable X is the same as the impact of deviations from that mean within a regression context. This is something we test for and suggest an alternative approach which in many respects combines fixed and random effects.

3.2 panel data techniques

Although panel data analysis has a several advantages, there are disadvantages with its use such as the unobserved heterogeneity, although in reality this problem also affects cross section data, but in this case we can do little about it. This biases the results if the right hand side variables are correlated with the unobserved heterogeneity.

Usually we use two techniques for the panel analysis, the fixed and the random effects. Firstly we need to discuss the mechanism of the fixed effects in order to pave the way for further exploration on the reasons behind the coefficients changes and contradictory signs of the coefficients**.** The fixed effects model is applied for controlling the variables that are time invariant, these variables are omitted variables that differ across the individuals (in our case countries), and it helps in monitoring the effect of the explanatory variables on the dependent variable by allowing us to focus on the changes that take place over time. Fixed effects effectively creates dummy variable for each category, each dummy variable removes one degree of freedom from the model. Dummies are considered as a part of the intercept. The attractiveness of a fixed effects model is its ability to control for all fixed characteristics of the individuals. Thus, fixed effects reduces potential bias.

With pooled panel analysis using OLS we would have biased estimates, unobserved heterogeneity where omitted variables arising from many individual characteristics not being observed, are correlated with variables which are observed.

$$Y_{it} = \beta_0 + \beta_1 x_{1it} + \beta_2 x_{2it} + \ldots + \beta_k x_{kit} + \varepsilon_{it} \tag{3.1}$$

Where ε_{it} is an error term and can be written as

$\varepsilon_{it} = \lambda_i + u_{it}$

λ_i is a composite error term that is supposed to be constant across individuals or countries and stands for individual effect. $u_{it} \sim N(0, \sigma_u^2)$ is a normally distributed random error.

To incorporate the time influence, the error term can be written as

$\varepsilon_{it} = \lambda_i + \mu_t + u_{it}$

Where μ_t stands for time effect. We will not do this in our analysis.

Fixed effects assume λ_i as constant for each category,

$$y_{it} = (\beta_0 + \lambda_i) + \beta_1 x_{1it} + \beta_2 x_{2it} + \ldots + \beta_k x_{kit} + u_{it} \tag{3.2}$$

The functional form of the fixed effects can be written in its simplest form,

$$Y_{it} = (\beta_0 + \lambda_i) + X_{it}\beta + u_{it} \tag{3.3}$$

The intercept varies across groups and potentially time. Estimating a substantial number of coefficients relating to dummy variables causes obvious problems. To control for the unobserved heterogeneity, the fixed effects model can proceed as such:

$$Y_{it} = \beta_0 + \lambda_i + \beta_1 x_{1it} + \beta_2 x_{2it} + \ldots + \beta_k x_{kit} + u_{it} \tag{3.4}$$

$$\begin{aligned} Y_{it} - Y_{it-1} = {} & \beta_0 + \lambda_i + \beta_1 x_{1it} + \beta_2 x_{2it} + \ldots + \beta_k x_{kit} + u_{it} - \beta_0 - \lambda_i - \beta_1 x_{1it-1} - \beta_2 x_{2it-1} - \\ & \ldots - \beta_k x_{kit-1} - u_{it-1} \end{aligned}$$

$$Y_{it} - Y_{it-1} = \beta_1 (x_{1it-1} - x_{1it-1}) + \beta_2 (x_{2it} - x_{2it-1}) + \ldots + \beta_k (x_{kit} - x_{kit-1}) + (u_{it} - u_{it-1})$$

$$\Delta Y_{it} = \beta_1 \Delta x_{1it} + \beta_2 \Delta x_{2it} + \ldots + \beta_k \Delta x_{kit} + \Delta u_{it} \tag{3.5}$$

We can see from the last equation that the constant and individual effects are eliminated. We can use the deviation from the mean as an alternative for the first difference.

Let $\overline{x_{1i}}$ be the mean for variable x_1 for individual i, averaged across all time periods. Subtracting the mean of each variable from the variable gives:

$$Y_{it} - \overline{Y}_{i.} = \beta_0 - \beta_0 + \lambda_i - \overline{\lambda}_{i.} + \beta_1 (x_{1it} - \overline{x}_{1i.}) + \ldots + \beta_k (x_{kit} - \overline{x}_{ki.}) + u_{it} \tag{3.6}$$

We can notice that this subtraction leads to elimination of the constant and individual effects

$$Y_{it} - \overline{Y}_{i\cdot} = \beta_1 (x_{1it} - \overline{x}_{1i.}) + \ldots + \beta_k (x_{kit} - \overline{x}_{ki.}) + u_{it} \tag{3.7}$$

This is known as the within estimator (Wooldridge (2002), chapter10, p.267) and it deals with the variations within the individuals but not between them. This can be estimated using pooled OLS and is in effect the fixed effects estimator. The advantage here is the disappearance of λ_i, in a way that time constant unobserved heterogeneity no longer exists. We can also use (3.7) to determine the individual fixed effects, i.e. each λ_i.

3.2.1 Random effects model

When estimating we use the means of the individual or country then it is the between estimator. The Random Effects model is a combination of the Fixed Effects (within) estimator and the between estimator. The overall estimator is a weighted average of the within and between estimators. The random effects estimator uses the correct weights.

$$\overline{Y_i} = \beta \overline{X_i} + \overline{\varepsilon_i} \quad \text{weighted average} \tag{3.8}$$

Random effects can be expressed as

$$\begin{aligned} Y_{it} &= \beta_0 + \beta_1 x_{1it} + \beta_2 x_{2it} + ... + \beta_k x_{kit} + \varepsilon_{it} \\ Y_{it} &= \beta_0 + \beta_1 x_{1it} + \beta_2 x_{2it} + ... + \beta_k x_{kit} + \lambda_i + u_{it} \end{aligned} \tag{3.9}$$

Where $\varepsilon_{it} = \lambda_i + u_{it}$, λ_i is part of composite error term and supposed to be randomly distributed. We assume Cov(X_{it} , λ_i)=0 and thus OLS will not produce biased results, but the results may be inefficient, i.e. another technique, random effects, may be better. The random effects estimator is a weighted combination of the within and between estimators. If Cov(X_{it} , λ_i)≠o, then the RE estimator is biased.

To find an efficient estimator we need to find first the structure of the error and then use a generalised least squares estimator to find the estimated coefficients. The assumptions must hold if the estimator is to be efficient. These are:

$$\begin{aligned} &E(u_{it}) = E(\lambda_i) = 0; && E(u_{it}^2) = \sigma_u^2; \\ &E(\lambda_i^2) = \sigma_\lambda^2; && E(u_{it}\lambda_i) = 0 \quad \textit{for all } i,t \\ &E(\varepsilon_{it}^2) = \sigma_u^2 + \sigma_\lambda^2 \quad t = s; && E(\varepsilon_{it}\varepsilon_{is}) = \sigma_\lambda^2, \quad t \neq s; \\ &\textit{and} \\ &E(x_{kit}\lambda_i) = 0 \; \textit{for all } k,t,i \end{aligned}$$

Then the random effects estimator is a matrix-weighted average combination of the within and between estimators (Bryman and Hardy, 2009, p.340; Kennedy, 2003, p.307). Random effects can be viewed as the application of the generalised least squares (GLS) estimator. Alternatively, the RE estimator can be applied by using pooled OLS but after the following transformation:

$$(Y_{it} - \theta\overline{Y_i}) = \beta_0(1-\theta) + \beta_1(x_{it} - \theta\overline{x_i}) + \{(1-\theta)\lambda_i + (\varepsilon_{it} - \theta\overline{\varepsilon_i})\} \tag{3.10}$$

where $\theta = 1 - \dfrac{\sigma_u}{\sqrt{T\sigma_\lambda^2 + \sigma_u^2}}$

$0<\theta<1$

If $\theta=1$, then FE and RE estimators are equal
If $\theta=0$, then RE estimator is identical with pooled OLS estimator

When the RE estimator is biased, the magnitude of θ will dominate the degree of biasedness, in case $\sigma_\lambda^2 > \sigma_u^2$, then $\theta \to 1$, RE and FE estimators coincide, because the variability of the individual effect is large relative to the random error, on the other side, when $\theta \to 0$ it is typical for the OLS estimator because $\sigma_\lambda^2 < \sigma_u^2$.

3.3 The methodology of extensions and reflections on fixed effects

We now integrate the above theoretical discussion with our work. Given an equation:

$$Y_{it} = X_{it}\beta + u_{it} \tag{3.11}$$

where i is the i'th unit of observation (country), t the time period and u_{it} is a randomly distributed normal error term. Assume for the moment that X_{it} is a single explanatory variable. This can be transformed by subtracting and adding the mean of X_{it} ($\overline{X_i}$) for each country:

$$Y_{it} = (X_{it} - \overline{X_i})\beta_d + \overline{X_i}\beta_m + u_{it} \tag{3.12}$$

That $\overline{X_i}$ is a single variable comprising of the means for each unit i over the T time periods. In effect, in fixed effects, we replace the separate means $\overline{X_i}$ by a set of dummy variables operative for each country. This is done in order to remove any unobserved heterogeneity at the unit level with which the X variables might be correlated. It is possible that $\overline{X_i}$ is correlated with u_{it}, e.g. countries may differ in terms of their growth dependent upon geographical characteristics such as whether they have a coast line. If X_{it} is correlated with these characteristics, it will pick up some of their influence. This will lead to biased estimates for all the coefficients. This is the bias we referred to earlier. Of course in the case of a coast line we can insert a dummy variable and this heterogeneity is no longer observed. But for other potential impacts such as 'work ethic' this may not be the case. Including dummy variables for each country removes this problem, albeit at the cost that we can no longer include our coast line dummy variable, nor indeed any variable which measures the unchanging characteristic of a country. There is however an implicit and seldom stated assumption in this, that the impact of the mean and deviations from the mean on Y in (3.12) are the same and hence their coefficients are the same. That is in the following:

$$Y_{it} = (X_{it} - \overline{X_i})\beta_d + \overline{X_i}\beta_m + u_{it} \tag{3.12}$$

$\beta_d = \beta_m$. But is this always the case? Take for example the impact of rainfall on a country's growth rate and further take the example of two countries. Country A typically has low rainfall, e.g. 20 inches a year. Country B has double of that. Now suppose in a given year rainfall is the same for both countries at 30 inches. Will the impact on growth be identical? Probably not. Countries will adapt to their average rainfall. Country A will have learned to become more frugal in its use of water than country B. It will tend to use it less for purposes such as watering the garden and cleaning the car. Industry too will in country A have adopted technologies which are less water intensive. So for country A, a rainfall of 30 inches will cause no inconvenience because of shortages, although excess water may cause problems for the infrastructure – to, for example, dirt roads. Country B on the other hand may feel the impact of shortages. Agriculture may be adversely affected as may water intensive industries. It is not just rain and other geographical variables which can have such a dual impact; inflation and corruption are two other such variables.

In this case fixed effects will give different results to either OLS or random effects, but not for reasons of endogeneity or unobservable heterogeneity. The fixed effects estimator will estimate β_d, the coefficient on the difference from the mean variables. The between effects estimate will tend to capture β_m, the coefficient on the means. OLS and random effects will then be a weighted average of the two, with its coefficient not really reflective of either effect. How then to proceed? We suggest the following.

First estimate equation (3.12) with dual coefficients for both the mean (β_m) and the difference from the mean (β_d) using OLS or random effects as appropriate. Then test to see if the coefficients (β_m and (β_d) are significantly different. If they are it could be due to either the dual impact of the variable, or because of unobservable heterogeneity with the mean picking up other country specific impacts on the dependent variable. Secondly, estimate the regression using fixed effects, in effect simply estimating the impact of the differences (β_d) then compare the fixed effects with the random effects /OLS ones. How is this different to the standard approach? It differs in the inclusion of more country based dummy variables relating to the means of the difference variables when estimating random effects. In addition as many other country dummy variables as may plausibly impact on the dependent variable should be included, bearing in mind degrees of freedom constraints. The appropriate test to compare the two equations is then not the Hausman test; this will just test for bias in the difference variables, whereas we are more interested in bias in the country means. For this we will have to compare the explanatory power of the fixed and random effects /OLS equations. If the fixed effects one is not significantly better we can conclude that the country specific variables including the means of the X's are fully capturing all the country specific effects. There is then no unobserved heterogeneity which is left unexplained by this regression and the coefficients on the mean variables are unbiased in the random effects /OLS equation. If there is a significant difference, then we are left in uncertainty. We know that the mean coefficients are significantly different from the difference coefficients (β_m is significantly different from (β_d) in (3.12), but we will not know whether this is because there is a genuine difference between the impacts of the means and the differences, or whether it is because of problems with unobservable heterogeneity biasing β_m. The only thing we can be confident of is in the impact of the differences (β_d).

3.4 Empirical analysis

We now illustrate this methodology.

3.4.1 Testing for fixed effects using the mean and the difference from the mean in regression panels

The impact of variables of interest like ratio of water utilization (ρ) and BOD (a measure of water pollution termed biological oxygen demand) on growth or GDP per capita (Represented by Y), can be written in the form,

$$Y_{it} = X_{it}\beta + \gamma\rho_{it} + \gamma BOD_{it} \tag{3.13}$$

Y_{it} is a dependent variable, X_{it} is a Kx1 vector of other explanatory variables, where i, denotes the country at time t. Instead of dealing with each individual year observation in terms of how much it differs from the previous year for the same country i, we can deal with the amount that each variable differs from the its average for each country i, therefore, equation (3.13) can be rewritten as:

$$Y_{it} = X_{it}\beta + \gamma(\rho_{it} - \overline{\rho_i}) + \gamma\overline{\rho_i} + \lambda(BOD_{it} - \overline{BOD_i}) + \gamma\overline{BOD_i} \tag{3.14}$$

Taking BOD as a reference for our interpretation, $\overline{BOD_i}$ is the average value of BOD for country i over all time periods. The assumption is implicit; the impact of deviations from the average $(BOD_{it} - \overline{BOD_i})$ is the same as the impact of the average $\overline{BOD_i}$ both have the coefficient γ. This is what fixed effects effectively assumes. It includes $\overline{BOD_i}$ with all the other country fixed effects, and measures the impact of $(BOD_{it} - \overline{BOD_i})$ on growth assuming this is also representative of the impact of the average $\overline{BOD_i}$. In many cases this is not irrational, but with climate variables it may be less reasonable. Water is a natural renewable resource whose availability is restricted to conditions like geography, climate change, and rainfall fluctuations. The impact of average BOD may well differ from that of deviations from it.

In the event the two impacts differ, fixed effects is inappropriate. How to test for this? In the random effects and OLS equations include both $(BOD_{it} - \overline{BOD_i})$ and $\overline{BOD_i}$, and see whether the two coefficients are significantly different from each other. If they are it suggests that fixed effects is inappropriate and random effects should be used to estimate an equation with both means and differences from means.

As we mentioned before, the fixed effects is picking up as significant differences between countries. But other variables **X** may vary between countries and these may be sufficient to fully explain these country differences. We here interpret our analysis starting from the previously explained techniques for fixed effects. We dropped considering the difference of observations from year to year and started to consider the difference of each variable from its mean. Taking into consideration the mean of the variables and the deviation from the mean, we want to explore whether the difference from the mean and the mean of the explanatory variables are giving the same impact on the dependent variable in the OLS and random variables models, and we run the fixed effects using the base variables, due to the fact that fixed effects catch both these impacts in the mechanism.

We calculated the mean and the difference from the mean for each explanatory variable; we used these two new variables to replace the one variable in our model. Taking BOD as an example, we replaced *BOD* in the regression for OLS and random effects with $(BOD_{it} - \overline{BOD_i})$ and $\overline{BOD_i}$, while keeping the variable as BOD in the fixed effects.

The results are represented in tables (3.1), (3.3) and (3.5) the models we used here are as follows

For OLS and random effects

$$GDPpercapita = \beta_0 + \beta_1(\rho_{it} - \overline{\rho_i}) + \beta_2\overline{\rho_i} + \beta_3(\rho_{it}^2 - \overline{\rho_i^2}) + \beta_4\overline{\rho_i^2} + \beta_5(BOD_{it} - \overline{BOD_i}) + \beta_6\overline{BOD_i} + \beta_7(BOD_{it}^2 - \overline{BOD_i^2}) + \beta_8\overline{BOD_i^2} \quad (3.15)$$

$$GDPpercapita = \beta_0 + \beta_1(\rho_{it} - \overline{\rho_i}) + \beta_2\overline{\rho_i} + \beta_3(\rho_{it}^2 - \overline{\rho_i^2}) + \beta_4\overline{\rho_i^2} + \beta_5(BOD_{it} - \overline{BOD_i}) + \beta_6\overline{BOD_i} + \beta_7(BOD_{it}^2 - \overline{BOD_i^2}) + \beta_8\overline{BOD_i^2} + \beta_9(X_{it} - \overline{X_i}) + \beta_{10}\overline{X_i} \quad (3.16)$$

Where ($X_{it} - \overline{X_i}$) stands for the difference from mean $\overline{X_i}$ of the remaining explanatory variables that we are using in this chapter and previously used in chapter two and these are Gini index, Inflation, Population growth, Political right index, corruption, Sch1ry , Sch2ry , trade as a per cent of GDP.

And for fixed effects:

$$GDPpercapita = \beta_0 + \beta_1\rho_{it} + \beta_2\rho_{it}^2 + \beta_3BOD_{it} + \beta_4BOD_{it}^2 \quad (3.17)$$

$$GDPpercapita = \beta_0 + \beta_1\rho_{it} + \beta_2\rho_{it}^2 + \beta_3BOD_{it} + \beta_4BOD_{it}^2 + \beta_5X_{it} \quad (3.18)$$

Where **X** stands for the above listed variables

In effect, we are comparing (i) the coefficients β_1 and β_2, e.g., from (3.15) to see if they are significantly different and (ii) the explanatory power of equations (3.15) and (3.17). If there is no difference in the latter, it will mean that the two means of ρ_i and ρ_i^2 are fully capturing country differences in GDP per capita. This may be unlikely, but not so unlikely when we come to compare (3.16) with (3.18). The equations with the percentage of growth and average of five years growth as dependent variables are:

For OLS and random effects

$$Growth = \beta_0 + (lGDPpc - \overline{lGDP}_{pc}) + \beta_1(\rho_{it} - \overline{\rho_i}) + \beta_2\overline{\rho_i} + \beta_3(\rho_{it}^2 - \overline{\rho_i^2}) + \beta_4\overline{\rho_i^2} + \beta_5(BOD_{it} - \overline{BOD_i}) + \beta_6\overline{BOD_i} + \beta_7(BOD_{it}^2 - \overline{BOD_i^2}) + \beta_8\overline{BOD_i^2} \tag{3.19}$$

$$Growth = \beta_0 + (lGDPpc - \overline{lGDP}_{pc}) + \beta_1(\rho_{it} - \overline{\rho_i}) + \beta_2\overline{\rho_i} + \beta_3(\rho_{it}^2 - \overline{\rho_i^2}) + \beta_4\overline{\rho_i^2} + \beta_5(BOD_{it} - \overline{BOD_i}) + \beta_6\overline{BOD_i} + \beta_7(BOD_{it}^2 - \overline{BOD_i^2}) + \beta_8\overline{BOD_i^2} + \beta_9(X_{it} - \overline{X_i}) + \beta_{10}\overline{X_i} \tag{3.20}$$

For fixed effects

$$Growth = \beta_0 + lGDPpc + \beta_1\rho_{it} + \beta_2\rho_{it}^2 + \beta_3 BOD_{it} + \beta_4 BOD_{it}^2 \tag{3.21}$$

$$Growth = \beta_0 + lGDPpc + \beta_1\rho_{it} + \beta_2\rho_{it}^2 + \beta_3 BOD_{it} + \beta_4 BOD_{it}^2 + \beta_5 X_{it} \tag{3.22}$$

The regression results are included in tables (3.1), (3.3) and (3.5), after running the regressions in this form we noticed the figures are not much different from the results in the previous chapters for the coefficient differences between fixed and random effects.

We perform specific significance tests to be able to make claims about the differences among these regression coefficients. The tests give an F statistic, and are a way of testing the significance of particular explanatory variables in a statistical model. Specifically we test to see whether the mean and difference coefficients are significantly different for the specific variables. We can compare the regression coefficients among these variables to test the null hypothesis coefficient on variable 1 is different from the coefficient on variable 2 after OLS regression. This test is a conceptual form to see whether $\beta_d = \beta_m$ following on from the previous discussion. This took place directly after running the OLS regression for each model and we compared the coefficients of different predictors to see if we can reject the null hypothesis that the coefficients are equal.

The null hypothesis that we are testing

H_o: $\beta_{mean} = \beta_{difference}$

H_A: $\beta_{mean} \neq \beta_{difference}$

Altman (1991) uses a t-test to check whether the parameter is significant. Here we performed a test of inequality for two of our coefficients (those on X_1mean= X_1 difference). If the test is significant, then we would conclude that the parameters associated with these variables are significantly different, so that the means and differences should be included separately in the model. If the test is not significant then these explanatory variables can be omitted from the model, which can be run simply with X. Here the OLS is similar to random effects in being a weighted average of the within and between estimators.

After dropping the insignificant variables we notice that the large changes in the estimated regression coefficients that we observed in the previous chapter seemingly disappeared, the results are included in tables 3.2, 3.4 and 3.6. We reported a calculated R^2 and an adjusted $\overline{R}^2$ and the root mean squared error. Adjusted R squared $\overline{R}^2$ used for many reasons, one of which is that adjusted $\overline{R}^2$ allows for the degrees of freedom associated with the sums of the squares. So when new explanatory variables are added, the residual sum of squares decreases or remains the same. For this reason, adjusted $\overline{R}^2$ is more accurate goodness-of-fit measure than R^2.

3.4.2 The Results

In general this procedure is to determine and examine whether the fixed effects is applicable here or not. We initially focus on the regressions where the dependent variable is GDP per capita.

i- LGDP per capita as a dependent variable

Let us illustrate the results with reference to Table (3.1). Columns 2 and 3 show the results with fixed and random effects (random effects with diff and mean). The coefficients are now very similar

Variables with 'similar' values of coefficients (from table 3.1)

	Column (2)(FE)		Column (3)(RE)
ρ	-0.956***	ρ *diff*	-1.032**
ρ^2	2.262***	ρ^2*diff*	2.454**

The two are very close together. This it appears that the fixed effects is capturing the difference from the mean as we argued. However, when we compare now the coefficients of the mean and the difference from the mean in column (3) we get

Column (3) in table 3.1	
ρ *mean*	0.001
ρ^2*mean*	-0.007

These are very different from the difference coefficients, but neither of them is significant. So we get the result so far that what impact on GDP per capita are differences from the mean for the ratio of water utilization, not the mean of ρ itself. This is counter to the assumption behind fixed effects, where both are assumed equal. Moving to the BOD variable in the model, comparing the results of the fixed and random effects of columns (2) and (3),

Variables from table 3.1

Column (2)(FE)		Column (3)(RE)		Column(3)(RE)	
Bod	9.148***	*Bod diff*	9.947***	*Bod mean*	0.168**
Bod^2	-0.542***	*Bod*^{2}*diff*	-0.542***	*Bod*^{2}*mean*	-0.294***

We also noticed that the fixed effects here is capturing the difference from the mean effect of variables, which indicates that the ratio of water utilization and the BOD are affecting the GDP per capita in their difference from the mean. Also, we can see that the mean of BOD is also affecting on GDP per capita.

Looking at the goodness of fit of columns (2) which is equal to 0.233, it is higher than that of the OLS regression (0.12). This might suggest that the fixed effects in this case is the suitable model for the impact of the ratio of water utilization and BOD on GDP per capita, and is consistent with our finding in chapter 2. On the other hand, it may mean that there is no bias per se, but that other country characteristics are impacting on the dependent variable, which we are not capturing in our means/differences model. But to accept fixed effects, means we accept the coefficients relating to the mean and the differences are equal. Yet we can see from the coefficients reported above that this appears unlikely.

Moving to the regressions of the model presented in columns (4), (5) and (6) of table (3.1) with the additional variables to see the impact within the macroeconomic framework, the most interesting results are:

Variables from table 3.1

Column (5)(FE)		Column (6)(RE)		Column(6)(RE)	
Bod	0.472***	*Bod diff*	1.785***	*Bod mean*	0.125
Bod^2	-0.958***	*Bod*^{2}*diff*	-3.904***	*Bod*^{2}*mean*	-0.415
Gini	1.039***	*Gini diff*	0.133	*Gini mean*	*-1.055*
Corrupt	-0.013**	*Corrupt.diff*	-0.038***	*Corrupt.mean*	0.398***

These results indicate that the fixed effects is capturing just the difference from the mean for the variables' effect on the GDP per capita. From column (4) we can see that the goodness of fit of the OLS regression (0.791) is higher than that of the fixed effects (0.687). But using the calculated[19] R^2 by using the correlation coefficient between the predicted value and the actual variables, we find the goodness of fit stands as 0.7914 for the OLS and 0.9956 for the fixed effects. Hence this suggests that our mean variables are not capturing the full extent of unobserved heterogeneity. At the same time, the OLS and random effects regressions, suggest differences between the mean and the difference from the mean impact of several variables, which leave us in confusion which is the suitable model. We need to explore this issue.

[19] This is the correlation between the predicted value of the regression and the actual value.

After exploring the behaviour of the estimated coefficients, we are going to test in order to compare the regression coefficients among the two groups of variables, and also in order to capture how the fixed effect differs from the random effects, the null hypothesis

Ho: $\beta_d = \beta_m$

In this case we are going to test for the regression coefficients of the variable mean and difference from the mean for the OLS model in column (4), we test the null hypothesis

H_o: $\beta_{mean} = \beta_{difference}$

H_A: $\beta_{mean} \neq \beta_{difference}$

The results of this test are listed in table 3.1.1-Appendix 3.I. If p <0.05, the null hypothesis can be rejected and the regression coefficients do indeed significantly differ. Hence this questions the validity of fixed effects. Among the insignificant variables were BOD (p=0.1237), BOD^2 (p=0.6236), Gini index (p=0.2372), Sch1ry (p=0.3124), Sch2ry (p=0.3919), trade % GDP (p=0.8101), which indicates the acceptance of the null hypothesis for these variables and the regression coefficients do not significantly differ, their p>0.05.

<u>Test for equality of mean and difference coefficients From table 3.I.1</u>

ρ	22.49***	*popgrwth*	7.42***
ρ^2	22.35***	*prindex*	345.21***
BOD	2.37 (p=0.1237)	*corrupt*	262.77***
BOD^2	0.24 (p=0.6236)	*sch1ry*	1.02 (p=0.3124)
Gini index	1.40 (p=0.2372)	*sch2ry*	0.73 (p=0.3919)
Inflation	5.54**	*tradeofgdp*	0.06 (p=0.8101)

We proceed by re-estimating our models after replacing the insignificantly different means and differences by just the original variables, i.e. instead of BOD*mean* BOD*diff* we use BOD as an explanatory variable, the same for BOD^2, Gini index, Sch1ry, Sch2ry and trade% GDP. That is the impact of the difference from the mean is the same as that of the mean for these variables and hence we can just include the variable itself. The regression results are listed in table (3.2).

Variables with 'similar' values of coefficients (from table 3.2)

variable	Column(1) (OLS)	Column(2) (FE)	Column(3) (RE)
ρ diff	1.865*		0.223***
ρ		0.220***	
ρ^2*diff*	-4.624*		-0.562***
ρ^2		-0.548***	
Bod	0.161***	0.472***	0.144**
corruptdiff	-0.0336		-0.0111*
corrupt		-0.013**	

These above results for the regression with the *fixed effects* included all the original variables. We now run the regression with the three models containing the same variables, in other words, all variables in difference and mean *except for the insignificantly different variables*. In this case, they are replaced by simply the original ones (i.e. X, rather than the mean and difference of X). The results in column (4) contain the new FE that is to be compared with (1), (2) and (3) in table (3.2).

Variables with close values of coefficients (from table 3.2)

Variable	Column(1) (OLS)	Column(2)(FE)	Column(4) (FE)	Column(3) (RE)
ρ diff	1.865*		0.224***	0.223***
ρ		0.220***		
ρ^2*diff*	-4.624*		-0.562***	-0.562***
ρ^2		-0.548***		
Bod	0.161***	0.472***	0.284**	0.144**
corruptdiff	-0.034		-0.011*	-0.011*

Different coefficients

variable	Column(1) (OLS)	Column(4) (FE)	Column(3) (RE)
ρ mean	0.008***	0	0.003
ρ^2*mean*	-0.041***	0	-0.013
BOD^2	-0.498***	-0.591*	-0.31

Looking at the estimated *ρ* estimator coefficients, we can see that the FE with the original variables and with the difference and the mean variables are giving the same impact on the GDP per capita and both coefficients are significant, the FE in column 4 gives extended evidence that the FE is just capturing the difference from the mean effect. The zero (0) coefficients indicate that when both the difference and the mean of a variable X is included in the fixed effects regression it will only estimate the difference coefficient not the mean coefficients. That is also consistent with the goodness of fit given by 0.9956 for both the FE models and with the calculated correlation coefficients related to the calculated R^2, the calculated adjusted R^2 also did not change much for the FE giving (0.9956) for both columns 2 and 4. We now compare the root mean square error from the different equations. First we compare those from columns (2) and (3). We can see that the root mean square error of the former, estimated by fixed effects, is smaller (0.103) than the latter, estimated by random effects with the mean and difference variables included (0.109). This suggests that the fixed effect is still picking up some non-changing country effects which our country means are failing to do. This still leaves open the possibility that some of our mean variables are correlated with this unexplained fixed country impact. However, we should also bear in mind that the use of fixed effects uses up degrees of freedom and hence the fall in the rmse may not be significant. We do not consider this further, at this stage, but proceed to the final equation. This has omitted the insignificant variables; we rerun the regression of the three models, to see the behaviour of the variables that have a different impact of the difference and the mean, from columns (5), (6) and (7):

Variables with close values of coefficients (from table 3.2)

variable	Column(6)(FE)	Column(7)(RE)
ρ diff	-1.136***	-1.133***
ρ^2*diff*	2.714***	2.706***
Infdiff	-0.00114*	-0.00114*

From the regression variables, the RE is capturing both the difference and the mean effect, and since the rmse value of the RE (0.184) is not much different from that of FE (0.183), this suggests that the random effects is the inappropriate model for the impact of the ratio of water utilization and BOD on the GDP per capita. That may solve the confusion that we have in the first regression of the goodness of fit of the RE and the OLS. But looking at the calculated goodness of fit, we notice that (R^2 = 0.9882) of FE is higher than that of OLS and RE. Also, taking into consideration that the value of adjusted R^2 did not change much (0.9956 in column 2 and 0.9872 in column 6), while the adjusted-R^2 of both the OLS and the RE decreased between first columns 1 (0.6933) and 3 (0.6787) and the columns that excluded the insignificant variables (Column 5, adj-R^2=0.6215 and column 7, adj-R^2=0.6061). All of these facts indicated that the mean variables that are unreadable in this FE (column 6) are related to the unobserved heterogeneity and that in this case there is still a case that FE is explaining more than OLS or random effects.

ii Annual growth as a dependent variable

We now turn to examine the results with growth as the dependent variable. Moving to panels of percentage of growth with our variables, the situation is not the same as with GDP per capita. In the first panel of table (3.3), looking at the results

Variables from table 3.3

Variable	Column(1)(OLS)	Column(3)(RE)	Variable	Column(2)(FE)
ρ diff	-4.950*	-5.468**	*ρ*	-6.408***
ρ^2diff	0.131*	0.144**	*ρ^2*	0.167***
ρ mean	-0.018**	-0.019***		
ρ^2mean	0.001**	0.001***		

It is apparent that the fixed effect in column (2) is capturing the difference from the mean which are significant at 1% significant level, although the mean results are significant, the values are much less than those of the first two lines. Hence for growth it appears that deviations from the mean are more important than the means themselves, which perhaps is as expected. That also appears in the columns (4) through (6). An example of the results is:

Variables from table 3.3

	Column(4)(OLS)	Column(6)(RE)		Column(5)(FE)
Bod diff	-1.731***	-1.635***	*Bod*	-1.675***
Bod^2 diff	0.346***	0.326***	*Bod^2*	0.337***
Bod mean	0.101***	0.100***	*Gini*	-0.129***
Bod^2 mean	-0.039***	-0.038**	*inf*	-0.0103***
Ginidiff	-0.075**	-0.103***		
infdiff	-0.0104***	-0.0101**		

This indicates that both the RE and the FE are capturing the impact of differences from the mean variables on the annual growth. After exploring the results of the differences and the means of the variables in table (3.3) we run the test of regression coefficients in the same way as mentioned after the OLS regression on the difference and the mean variables. That is we test for equality between the difference and mean variables. The insignificant variables are ρ (p=0.9625), ρ^2 (p=0.9716), political rights index (p=0.21), corruption (p=0.66) and sch2ry (P=0.4224).

<u>Test for equality of mean and difference coefficients From table 3.I.2</u>

lgdppc	20.18***		
ρ	0.14 (p=0.9625)	*popgrwth*	29.09***
ρ^2	0.13 (p=0.9716)	*prindex*	1.60 (p=0.21)
BOD	42.84***	*corrupt*	0.19 (p=0.66)
BOD^2	30.43***	*sch1ry*	6.27**
Gini index	3.90*	*sch2ry*	0.64 (P=0.4224)
Inflation	19.98***	*tradeofgdp*	4.89*

So we accept the null hypothesis that these variables' coefficients for difference and the mean are equal in their impact. Replacing these with the original variables (i.e. replacing the mean and the difference from the mean of X with just X) and rerunning the regression analysis, but keeping the original variables with the FE, the results are included in columns (1) through (3) in table (3.4). From the table it is apparent that the fixed effects in column (2) is reflecting a close value of regression coefficients with those of OLS and random effects, except for those where the twin variables are replaced with the single original ones. To illustrate we chose these results from the table (3.4):

<u>Variables with close values of coefficients (from table 3.4)</u>

Variable	Column(1)(OLS)	Column(2)(FE)	Column(3)(RE)
Bod diff	-1.620***		-1.579***
bod		-1.675***	
Bod^2 diff	0.319***		0.311***
Bod^2		0.337***	
Gini	-0.046**	-0.129***	-0.075**
infdiff	-0.01***		-0.01**
inf		-0.0103**	

We rerun the regression replacing just the original variables in OLS, fixed and random effects. We can see from the regression in column (4, table 3.4) of the fixed effects that is containing the differences from the mean and the mean of the significant variables and the original insignificant variables:

Variables with close values of coefficients (from table 3.4)

variable	Column(1)(OLS)	Column(4)(FE)	Column(3)(RE)
$lgdp_{pc}diff$	4.966***	4.372***	4.496**
BODdiff	-1.620***	-1.661***	-1.579***
BOD^2diff	0.319***	0.334**	0.311***
tradegdpdiff	0.018***	0.042*	0.022**

Different coefficients

variable	Column(1)(OLS)	Column(4)(FE)	Column(3)(RE)
$lgdp_{pc}mean$	-0.016	0	-0.170
ρ	-0.011***	4.231	-0.011**
ρ^2	0.001***	-0.107	0.001*
BODmean	0.097***	0	0.101***
BOD^2mean	-0.038***	0	-0.038**
Trade%gdpmean	0.0128***	0	0.0163*
P.r. index	0.144	-0.038	0.041

The zero coefficients for the mean variables with fixed effects are in a sense misleading. Fixed effects is estimating the difference from the means, but the mean effects are being picked up by the country fixed effects. We notice that the difference variables are approximately giving the same impact and significance levels among the OLS, fixed and random effects, as well as the signs of the coefficients. After we drop the insignificant- original variables from the model, we rerun our regression to see the influence of the fixed effects variables and how the difference variables dominate the regression analysis and the results are included in columns (5) through (7).

Variables with close values of coefficients (from table 3.4)

variable	Column(5)(OLS)	Column(6)(FE)	Column(7)(RE)
BODdiff	-0.479***	-0.441**	-0.446**
BOD^2diff	0.0376**	0.0365*	0.0359*
Infdiff	-0.0143*	-0.0125***	-0.0145***

The fact that the estimator coefficients do not change much between the three models, again suggests that the impact of the means is relatively weak compared with the impact of the difference from the mean. Also the rmse values do not change much between the models, the FE model is not doing better than the RE model for estimating the effect of ρ and BOD on the percentage of growth in terms of explanatory power. However, looking at the calculated correlation coefficients and calculated goodness of fit for FE (0.3243) is higher than that of the RE (0.1815). In addition the rmse of the FE (3.31) is slightly lower than that of the RE (3.337). The calculated adj-R^2 does not tell us much, we can see from table 3.4 that moving between columns gave the following goodness of fit results:

From table 3.4

					After dropping of insignificant variables		
	Column(1) (OLS)	Column(2) (FE)	Column(3) (RE)	Column(4) (FE)	Column(5) (OLS)	Column(6) (FE)	Column(7) (RE)
Rmse	3.129	2.976	2.977	2.976	3.523	3.310	3.337
R^2(cal.)	0.3098	0.4129	0.3049	0.4124	0.046	0.3243	0.1815
R^2adj(cal.)	0.2951	0.4053	0.2900	0.4053	0.0361	0.3211	0.1729

The R^2 which may turn the decision towards the credibility of the FE. These are calculated R^2 by calculating the predicted value from the regression, where relevant including the country fixed effects, and finding the correlation between this and the actual variable.

iii <u>*The rate of five years growth as a dependent variable*</u>

Finally, we look at the rate of five years growth as the dependent variable. From table (3.5), columns (1) through (6) we can see that the coefficients are

<u>Variables with close values of coefficients (from table 3.5)</u>

variable	Column(1)(OLS)	Column(2)(FE)	Column(3)(RE)
ρdiff	-9.583*		-10.94*
ρ		-11.53*	
$\rho^2 diff$	0.291*		0.324**
ρ^2		0.338**	
BODdiff	-17.15***		-18.39***
BOD		-18.81***	
$BOD^2 diff$	7.430**		8.464**
BOD^2		8.816**	

variable	Column(4)(OLS)	Column(5)(FE)	Column(6)(RE)
BODdiff	-5.900***		-7.428***
BOD		-7.496***	
$BOD^2 diff$	1.078***		1.456***
BOD^2		1.426***	

From the results we can see that the fixed effects regressions are capturing the differences from the mean and the variables like *ρ* and BOD are affecting the rate of five years growth by the difference from the mean rather than the mean. From the results of the variables it is very clear that the differences from the mean that are captured in the fixed effects regression are the most important effect on the rate of five years growth, although ρ mean and ρ^2 mean are both significant at the 1% significant level. In an extended exploration of the effect of these variables and coefficients, we repeated the regression of the last panel after replacing X mean and X diff with just X when the two are not significantly different. The affected variables are Gini index (p=0.2638), p.r.index (p=0.4259), corruption (p=0.1176) and Sch2ry (p=0.0881). We now run the regression using the original variables.

Test for equality of mean and difference coefficients From table 3.I.3

lgdppc	82.92***		
ρ	4.56*	*popgrwth*	15.92***
ρ^2	4.85*	*prindex*	0.63 (p=0.4259)
BOD	65.04***	*corrupt*	2.45 (p=0.1176)
BOD^2	35.96***	*sch1ry*	12.79***
Gini index	1.25 (p=0.2638)	*sch2ry*	2.92 (p=0.0881)
Inflation	40.30***	*tradeofgdp*	11.31***

We can see from the table (3.6) that the columns (1) through (3) are giving the same signs of the regression coefficient, also the coefficients values are close. Again in general the fixed effects original variables reflect the impact of the differences from the mean, rather than the mean per se

Variables with close values of coefficients (from table 3.6)

variable	Column(1)(OLS)	Column(2)(FE)	Column(3)(RE)
BODdiff	-5.687***		-7.101***
BOD		-7.496***	
BOD^2 *diff*	1.005***		1.356***
BOD^2		1.426***	
Gini	-0.219***	-0.439***	-0.365***

For more descriptions we show some of the regression of the columns (4) for the fixed effect with the difference from the mean and the mean together with the insignificant original variables, where the values of the striking variables are listed as:

Variables with close values of coefficients (from table 3.6)

Variable	Column(1)(OLS)	Column(4)(FE)	Column(3)(RE)
BODdiff	-5.687***	-7.496***	-7.101***
BOD^2 *diff*	1.005***	1.426***	1.356***
Gini	-0.219***	-0.439***	-0.365***
popgrwthdiff	-5.989***	-5.988***	-4.347***

Different coefficients

Variable	Column(1)(OLS)	Column(4)(FE)	Column(3)(RE)
BOD mean	0.286***	0	0.373***
BOD^2*mean*	-0.088***	0	-0.128**

Once more the fixed effect fails to estimate coefficients for the mean variables when the differences are also included. These are being picked up by the fixed effects and emphasise once more that fixed effects is picking up the differences from the mean. The fixed effects estimation is not capturing the mean effect and after dropping the insignificant or the original variables in our analysis, and rerunning the regression for the OLS, fixed and random effects

Variables with close values of coefficients (from table 3.6)

Variable	Column(5)(OLS)	Column(6)(FE)	Column(7)(RE)
ρ *diff*	20.98*	31.53***	23.13**
ρ^2*diff*	-0.525*	-0.786***	-0.581**
BODdiff	-1.603***	-1.363***	-1.231***
BOD^2 *diff*	0.160***	0.177**	0.133**
Infdiff	-0.068**	-0.098***	-0.062***

Different coefficients

Variable	Column(5)(OLS)	Column(6)(FE)	Column(7)(RE)
ρ *mean*	0.051	0	0.0680*
ρ^2*mean*	-0.003	0	-0.003*
BOD mean	0.056***	0	0.015
BOD^2*mean*	-0.005	0	0.002

Examining the dual impact on the dependent variable, due to the impact of both the differences from the mean and the mean of the variable, the variables in general are having the same impact on the dependent variable when estimated by different methods. If we look through the results in Table 3.6, we can see that the differences from the mean which is what the FE is estimating, is dominating this influence. Also, the values of the rmse (10.07) for FE is less than that of the RE (10.71), and the calculated correlation coefficients indicating that the goodness of fit for the FE (0.42758) is higher than that of RE (0.2173). This indicates that the appropriate model for the impact of the ratio of water utilization and the BOD on the rate of five years growth is the FE model. Looking at the calculated adjusted R^2 from table 3.6, we can see that, for the FE models in both columns (2) and (4), whether we use the original variables or the difference from the mean or the mean variables the change in the adjusted R^2 is the same. The adjusted R^2 in both FE models gives a smaller value than the calculated R^2. Whereas, the adjusted R squared for the OLS and the RE models changes slightly in a 11%- 14% range. The difference between the adjusted R^2 between OLS and fixed effects is not that great, but there is a slight indication that the FE model is better. Some of the unobserved heterogeneity is captured by the OLS and the RE models but the data suggests that the FE model still captures more.

From table 3.6

					After dropping of insignificant variables		
	Column(1)	Column(2)	Column(3)	Column(4)	Column(5)	Column(6)	Column(7)
	(OLS)	(FE)	(RE)	(FE)	(OLS)	(FE)	(RE)
Rmse	9.485	7.571	8.214	7.805	12.21	10.07	10.71
R^2(cal.)	0.4822	0.6346	0.4590	0.6457	0.2281	0.42758	0.2173
R^2adj(cal.)	0.4701	0.6298	0.4463	0.6411	0.2193	0.4250	0.2084

3.5 Conclusion

We used OLS, fixed and random effects in the previous chapter, chapter 2 to estimate the effect of the ratio of water utilization and BOD and other variable on growth. The Hausman test directed the decision towards the fixed effects. The problem with OLS and RE is that the variables may be correlated with country characteristics which impact on growth which we do not include in the model. If so then the coefficients will be picking up some of these unforeseen influences. We began by noting that the coefficients between random and fixed are different; this begins to questions the validity of fixed effects and to explore the reason behind the variations in coefficients we reflected on the nature of fixed effects. We added and subtracted a mean of each variable on the right hand side of the model.

$$Y_{it} = X_{it}\beta + u_{it}$$
$$Y_{it} = (X_{it} - \overline{X}_i)\beta_d + \overline{X}_i\beta_m + u_{it}$$

The fixed effects here assume the impact of the mean of X and difference of X is the same. We regressed using the OLS and random effects using the difference and the mean of each variable on the right hand side, but using the original variables for the fixed effects at the same time. We did this to see how the variables are behaving in fixed effects. The regressions results of all models indicated that the fixed effect is impacting on the GDP per capita and on growth in a manner which reflects the difference impact of the variables, rather than the impact of the mean. That is consistent with theory that we can add the mean to replace the dummy variables in the fixed effects approach. We mentioned before that the fixed effects effectively create dummy variables for each category. Each dummy variable removes one degree of freedom from the model. Here the FE is the within estimator and catches the difference of the variables from the mean, in general, we have to keep in mind that FE models study the causes of changes within the entity (Kohler and Kreuter, 2009, p.245)

To explore more the impact of the difference and the mean in the model on the dependent variable, we used test statistics to test for the null hypothesis that the difference and the mean variables are equal in their impact on the left hand side variable, if they are not it could be due to either the dual impact of the variable, or because of unobservable heterogeneity with the mean picking up other country specific impacts on the dependent variable. Hence this questions the validity of fixed effects. Significance tests rejected the null in several cases and we replaced the insignificant variables (that accepted that the null that the difference effect of X = the mean effect of X) by the original variable X in the model since their impact is the same on the dependent variable. This step gave us the opportunity to explore the effect of other variables and to test the validity of the fixed effects as the approved model in this case. Now if our mean augmented equation is as good as fixed effects, then it suggests that there are no omitted characteristics and no unobservable heterogeneity. And hence arguably we have no need to use FE. We used the root mean square error and the (calculated) adjusted R squared as our measures to test the fitting of the model. In the three cases, the GDP per capita, the percentage of growth and the rate of five years growth indicated that the FE is better than the RE for GDP per capita, i.e. the levels variable and for growth. We also see from the regression results that the BOD variable is proving to be more significant and its effect through the difference from the mean is consistent throughout the three models, which is agreeable with our results in chapter 2 that the quality of water is more significant in its impact on growth than the quantity of water itself.

The use of fixed effects in this case will tend to obscure the dual impact of a variable X on the dependent variable. It is not so much that fixed effects is biased, but that it will only capture the impact of differences in X, not the mean of X, and where the two differ this is only half the story. The regression analysis suggests that this is more of a problem in the levels regression. That is not unexpected. The initial illustration was with respect to countries adjusting their economies to average levels of rainfall. Recall from the earlier debate that water as a natural renewable resource its availability is restricted to conditions like geography, climate change, and rainfall fluctuations. These are considered to be exogenous effects in the model and can be correlated with the effect of water resources for the individual country. So, if these exogenous variables, that are not included in our model, are correlated with the dependent variable (GDP per capita and growth), then pooled cross section and random effects are insufficient and give biased estimators. Moreover, this distinction between fixed and random effects has similarities to the work of Mundlak (1978). This is more likely to be reflected in GDP per capita, a levels variable, rather than the rate of change of this variable. In other words growth tends to be more sensitive to fluctuations around the mean and GDP per capita to the mean. But even with growth there were some significant differences between the difference and mean coefficients.

Table 3.1: Regression of Log GDP per capita with the differences from the mean and the mean variables

Table 3.1: Dependent variable: Log GDP per capita

	(OLS)	(FE)	(RE)		(OLS)	(FE)	(RE)
	(1)	(2)	(3)		(4)	(5)	(6)
Constant	7.460***	35.98***	7.400***	Constant	18.02***	-43.77***	11.82
	(216.50)	(17.02)	(35.57)		(8.33)	(15.01)	(1.12)
ρdiff	0.0645		-1.032**	ρdiff	0.069		-0.592***
	(0.20)		(2.89)		(0.15)		(6.82)
ρ^2diff	-0.344		2.454**	ρ^2diff	-0.271		1.422***
	(0.42)		(2.73)		(0.23)		(6.43)
ρmean	0.003***		0.001	ρmean	0.001		-0.003
	(3.98)		(0.18)		(1.17)		(1.19)
ρ^2mean	-0.019***		-0.007	ρ^2mean	-0.003		0.016
	(4.64)		(0.28)		(0.68)		(1.38)
BODdiff	5.874***		9.947***	BODdiff	0.996*		1.785***
	(3.90)		(3.73)		(2.42)		(16.5)
BOD^2diff	-0.264		-0.578**	BOD^2diff	-1.629		-3.904***
	(2.27)		(2.87)		(1.68)		(13.60)
BODmean	0.188***		0.168**	BODmean	0.142***		0.125
	(21.57)		-2.82		(5.29)		(1.75)
BOD^2mean	-0.326***		-0.294***	BOD^2mean	-0.513***		-0.415
	(25.02)		(3.31)		(4.16)		(1.10)
ρ		-0.956***		Ginidiff	0.283		0.133
		(14.20)			(0.54)		(1.23)
ρ^2		2.262***		Ginimean	-0.237		-1.055
		(12.88)			(0.55)		(0.84)
BOD		9.148***		Infdiff	-0.001		-0.002
		(21.83)			(0.27)		(1.56)
BOD^2		-0.542***		Infmean	-0.040		-0.022
		(14.04)			(0.83)		(0.13)
				Popgrwthdiff	0.019		0.006
					(0.26)		(0.9)
				Popgrwthmean	0.162		0.493***
					(1.87)		(3.77)
				P.r.indexdiff	0.019		0.002
					(0.83)		(0.44)
				P.r.indexmean	-0.464***		-0.493***
					(16.31)		(5.15)

Table 3.1: Dependent variable: Log GDP per capita

	(OLS)	(FE)	(RE)		(OLS)	(FE)	(RE)
	(1)	(2)	(3)		(4)	(5)	(6)
				Corruptdiff	-0.053		-0.038***
					(1.91)		(7.00)
				Corruptmean	0.350***		0.398***
					(11.36)		(3.3)
				Sch1rydiff	0.0141*		-0.0011
					(2.29)		(0.79)
				Sch1rymean	-0.089***		-0.079*
					(11.96)		(2.17)
				Sch2rydiff	-0.006		-0.008***
					(0.73)		(3.64)
				Sch2rymean	-0.0129		0.0382
					(0.71)		(0.42)
				Trade%gdpdiff	0.003***		0.003***
					(5.28)		(12.15)
				Trade%gdpmean	0.003***		0.003**
					(5.2)		(3.0)
				Dummy variable	-0.640***	.	-1.002**
					(7.25)	.	(3.07)
				ρ		0.220***	
						(3.97)	
				ρ^2		-0.548***	
						(3.86)	
				BOD		0.472***	
						(5.28)	
				BOD^2		-0.958***	
						(4.45)	
				Gini		1.039***	
						(29.58)	
				Inf		-0.00014	
						(0.08)	
				Popgrwth		0.037***	
						(7.83)	
				P.r.index		0.018***	
						(5.64)	
				Corruption		-0.013**	
						(3.10)	
				Sch1ry		0.005***	
						(4.49)	
				Sch2ry		0.001	
						(0.49)	

Table 3.1: Dependent variable: Log GDP per capita

	(OLS)	(FE)	(RE)		(OLS)	(FE)	(RE)
	(1)	(2)	(3)		(4)	(5)	(6)
				Trade%gdp		0.001***	
						(5.22)	
N	3740	3740	3740	N	1500	1500	1500
R-sq	0.119	0.233		R-sq	0.791	0.687	
adj. R-sq	0.118	0.213		adj. R-sq	0.788	0.670	
rmse	1.525	0.370	0.397	rmse	0.75	0.103	0.137
R-sq (calc.)	0.1184	0.9415	0.1106	R-sq (calc.)	0.7914	0.9956	0.7729
adj. R-sq(calc.)	0.1165	0.9414	0.1087	adj. R-sq(calc.)	0.7878	0.9956	0.7691

t statistics in parentheses * p<0.05, ** p<0.01, *** p<0.001

Table 3.2: Regression of dependent variable Log GDP per capita with an amended specification[20] from table 3.1

Table 3.2: Dependent variable Log GDP per capita

						After dropping the insignificant variables		
	(OLS)	(FE)	(RE)	(FE)		(OLS)	(FE)	(RE)
	(1)	(2)	(3)	(4)		(5)	(6)	(7)
Constant	-38.36***	-43.77***	-40.16***	-38.79***	Constant	6.977***	7.717***	6.894***
	(3.87)	(15.01)	(25.41)	(26.08)		(54.67)	(1551.89)	(12.75)
ρdiff	1.865*		0.223***	0.224***	ρdiff	0.504	-1.136***	-1.133***
	(2.41)		(3.55)	(3.57)		(0.71)	(12.82)	(12.75)
ρ^2diff	-4.624*		-0.562***	-0.562***	ρ^2diff	-1.310	2.714***	2.706***
	(2.38)		(3.52)	(3.53)		(0.72)	(11.86)	(11.8)
ρmean	0.008***		0.003	.	ρmean	0.007***	.	0.002
	(4.66)		(1.07)	.		(4.27)	.	(0.72)
ρ^2mean	-0.041***		-0.013	.	ρ^2mean	-0.035***	.	-0.008
	(4.46)		(0.95)	.		(4.09)	.	(0.63)
BOD	0.161***	0.472***	0.144**	0.284**	Infdiff	-0.001	-0.001*	-0.001*
	(10.08)	(5.28)	(2.72)	(2.87)		(0.41)	(2.13)	(2.12)
BOD^2	-0.498***	-0.958***	-0.31	-0.591*	Infmean	-0.063***	.	-0.076
	(6.95)	(4.45)	(1.78)	(2.34)		(4.81)	.	(0.93)
Gini index	1.176***	1.039***	1.151***	1.124***	Popgrwthdiff	-0.182***	0.002	0.002
	(4.97)	(29.58)	(34.73)	(30.42)		(3.99)	(0.45)	(0.41)
Infdiff	0.005		0.001	0.001	Popgrwthmean	0.151***	.	0.277*
	(1.16)		(0.95)	(0.9)		(3.79)	.	(2.55)
Infmean	-0.093*		-0.089	.	P.r.indexdiff	0.076***	-0.016***	-0.016***
	(2.03)		(0.43)	.		(3.55)	(4.29)	(4.23)
Popgrwthdiff	0.003		0.045***	0.044***	P.r.indexmean	-0.258***	.	-0.247***
	(0.04)		(8.94)	(8.78)		(15.80)	.	(3.39)
Popgrwthmean	0.111		0.330*	.	Corruptdiff	-0.092***	-0.079***	-0.079***
	(1.62)		(2.02)	.		(3.30)	(15.61)	(15.59)
P.r.indexdiff	0.113***		0.013***	0.013***	corruptmean	0.608***	.	0.617***
	(4.27)		(4.19)	(4.15)		(24.83)	.	(5.68)
P.r.indexmean	-0.338***		-0.372***	.	Dummy variable	-0.779***	.	-0.993***
	(15.15)		(3.37)	.		(11.19)	.	(3.31)
Corruptdiff	-0.0336		-0.0111*	-0.0109*				
	(1.05)		(2.55)	(2.51)				
Corruptmean	0.454***		0.459**	.				
	(15.63)		(3.02)	.				

[20] Note: replacing the X diff and the X mean with X for the insignificant variables and the panel after dropping the insignificant variables (columns (5), (6) and (7)).

Table 3.2: Dependent variable Log GDP per capita

						After dropping the insignificant variables		
	(OLS)	(FE)	(RE)	(FE)		(OLS)	(FE)	(RE)
	(1)	(2)	(3)	(4)		(5)	(6)	(7)
Sch1ry	-0.026***	0.005***	0.005***	0.005***				
	(7.25)	(4.49)	(4.15)	(4.2)				
Sch2ry	0.0023	0.001	0.003	0.002				
	(0.4)	(0.49)	(1.4)	(1.37)				
Trade%gdp	0.003***	0.001***	0.001***	0.001***				
	(6.51)	(5.22)	(3.5)	(3.38)				
Dummy variable	-0.525***	.	-0.847*	.				
	(5.66)	.	(2.20)	.				
ρ		0.220***						
		(3.97)						
ρ^2		-0.548***						
		(3.86)						
Jnflation		-0.0001						
		(0.08)						
Popgrowth		0.037***						
		(7.83)						
P.r.index		0.018***						
		(5.64)						
corrupt		-0.013**						
		(3.10)						
N	1590	1590	1590	1590	N	2810	2810	2810
R-sq	0.684	0.687		0.665	R-sq	0.623	0.177	
adj. R-sq	0.680	0.670		0.647	adj. R-sq	0.621	0.138	
rmse	0.901	0.103	0.109	0.109	rmse	1.014	0.183	0.184
R-sq (calc.)	0.6841	0.9956	0.6474	0.9956	R-sq (calc.)	0.6232	0.9882	0.6079
adj. R-sq(calc.)	0.6803	0.9956	0.6431	0.9956	adj. R-sq(calc.)	0.6215	0.9882	0.6061

t statistics in parentheses * p<0.05, ** p<0.01, *** p<0.001

Table 3.3: Regression of Percentage of Growth with the differences from the mean and the mean variables

Table 3.3: Dependent variable: Annual growth							
	(OLS)	(FE)	(RE)		(OLS)	(FE)	(RE)
	(1)	(2)	(3)		(4)	(5)	(6)
Constant	-0.353	194.5**	-0.417	Constant	9.498	-142.3	18.59
	(0.46)	(2.92)	(0.42)		(1.08)	(1.03)	(0.95)
lgdp$_{pc}$diff	3.145***		3.082***	lgdp$_{pc}$diff	5.181***		4.729***
	(4.22)		(6.11)		(4.74)		(6.46)
lgdp$_{pc}$mean	0.283**		0.292*	lgdp$_{pc}$mean	0.141		0.0368
	(3.26)		(2.51)		(0.55)		(0.1)
ρdiff	-4.950*		-5.468**	ρdiff	-0.174		1.544
	(2.16)		(2.95)		(0.05)		(0.38)
ρ^2diff	0.131*		0.144**	ρ^2diff	0.004		-0.04
	(2.26)		(3.01)		(0.04)		(0.38)
ρmean	-0.018**		-0.019***	ρmean	-0.011		-0.005
	(2.68)		(3.84)		(0.95)		(0.38)
ρ^2mean	0.001**		0.001***	ρ^2mean	0.0005		0.0003
	(2.82)		(3.96)		(0.93)		(0.37)
BODdiff	-0.259*		-0.255	BODdiff	-1.731***		-1.635***
	(2.31)		(1.81)		(6.52)		(5.49)
BOD^{2}diff	0.0126		0.0124	BOD^{2}diff	0.346***		0.326***
	(1.64)		(1.14)		(5.5)		(4.09)
BODmean	0.005		0.004	BODmean	0.101***		0.1000***
	(0.71)		(0.46)		(6.28)		(4.31)
BOD^{2}mean	0.002		0.002	BOD^{2}mean	-0.039***		-0.039**
	(1.74)		(1.19)		(5.21)		(3.21)
lgdp$_{pc}$		2.966***		Ginidiff	-0.075**		-0.103***
		(5.85)			(2.81)		(3.50)
ρ		-6.408***		Ginimean	-0.028		-0.038
		(3.32)			(1.65)		(1.25)
ρ^2		0.167***		Infdiff	-0.0104***		-0.0101***
		(3.37)			(3.42)		(3.46)
BOD		-0.247		Infmean	0.0024		0.003
		(1.72)			(0.6)		(0.57)
BOD^2		0.0121		Popgrwthdiff	-2.158***		-2.065***
		(1.09)			(8.58)		(8.32)
				Popgrwthmean	-0.640**		-0.647*
					(3.11)		(1.96)
				P.r.indexdiff	0.0325		-0.00982

Table 3.3: Dependent variable: Annual growth

	(OLS)	(FE)	(RE)		(OLS)	(FE)	(RE)
	(1)	(2)	(3)		(4)	(5)	(6)
					(0.25)		(0.08)
				P.r.indexmean	0.246		0.178
					(1.6)		(0.77)
				Corruptdiff	-0.052		-0.062
					(0.30)		(0.40)
				Corruptmean	-0.151		-0.26
					(0.94)		(0.94)
				Sch1rydiff	0.013		0.015
					(0.7)		(0.85)
				Sch1rymean	-0.042**		-0.042
					(2.63)		(1.71)
				Sch2rydiff	0.043		0.055
					(1.25)		(1.05)
				Sch2rymean	-0.044		-0.121
					(0.50)		(0.61)
				Trade%gdpdiff	0.019***		0.023***
					(5.0)		(4.9)
				Trade%gdpmean	0.013***		0.017***
					(4.09)		(3.77)
				Dummy variable	-0.557	.	-0.549
					(1.46)	.	(0.75)
				$lgdp_{pc}$		4.471***	
						(5.69)	
				ρ		4.383	
						(1.02)	
				$ρ^2$		-0.111	
						(1.00)	
				BOD		-1.675***	
						(5.42)	
				BOD^2		0.337***	
						(4.11)	
				Gini		-0.129***	
						(3.34)	
				Inf		-0.010***	
						(3.41)	
				Popgrwth		-2.111***	
						(7.90)	
				P.r.index		-0.037	
						(0.26)	
				Corruption		-0.064	

Table 3.3: Dependent variable: Annual growth

	(OLS)	(FE)	(RE)		(OLS)	(FE)	(RE)
	(1)	(2)	(3)		(4)	(5)	(6)
						(0.41)	
				Sch1ry		0.0114	
						(0.63)	
				Sch2ry		0.063	
						(1.17)	
				Trade%gdp		0.041***	
						(4.88)	
N	2594	2594	2594	N	1011	1011	1011
R-sq	0.046	0.023		R-sq	0.314	0.161	
adj. R-sq	0.042	-0.016		adj. R-sq	0.295	0.089	
rmse	5.296	5.228	5.235	rmse	3.129	2.976	2.978
R-sq (calc.)	0.0456	0.1022	0.0455	R-sq (calc.)	0.3139	0.4129	0.3102
adj. R-sq(calc.)	0.0418	0.1005	0.0418	adj. R-sq(calc.)	0.2951	0.4053	0.2913

t statistics in parentheses * p<0.05, ** p<0.01, *** p<0.001

Table 3.4: Regression of the dependent variable Percentage of growth with an amended specification[21] from table 3.3

Table 3.4: Dependent variable: Annual growth

						After dropping the insignificant variables		
	(OLS)	(FE)	(RE)	(FE)		(OLS)	(FE)	(RE)
	(1)	(2)	(3)	(4)		(5)	(6)	(7)
Constant	3.453	-142.3	4.209	-130.9	Constant	3.026*	1.223***	4.111*
	(1.22)	(1.03)	(0.86)	(0.97)		(2.15)	(5.68)	(2.16)
$lgdp_{pc}$diff	4.966***		4.496***	4.372***	$lgdp_{pc}$diff	2.001***	1.021	1.735***
	(5.08)		(6.45)	(5.62)		(3.41)	(1.93)	(3.48)
$lgdp_{pc}$mean	-0.016		-0.17	.	$lgdp_{pc}$mean	-0.11	.	-0.268
	(0.07)		(0.54)	.		(0.70)	.	(1.21)
ρ	-0.011***	4.383	-0.011*	4.231	BODdiff	-0.479***	-0.441**	-0.446**
	(4.15)	(1.02)	(2.29)	(0.98)		(4.40)	(3.18)	(3.26)
ρ^2	0.001***	-0.111	0.001*	-0.107	BOD^2diff	0.038**	0.037*	0.036*
	(4.09)	(1.00)	(2.24)	(0.97)		(2.96)	(2.36)	(2.33)
BODdiff	-1.620***		-1.579***	-1.661***	BODmean	0.023***	.	0.021*
	(6.15)		(5.48)	(5.38)		(3.52)	.	(2.01)
BOD^2diff	0.319***		0.311***	0.334***	BOD^2mean	-0.002	.	-0.002
	(5.23)		(4.02)	(4.08)		(1.38)	.	(0.86)
BODmean	0.097***		0.101***	.	Infdiff	-0.014*	-0.013***	-0.015***
	(6.14)		(4.41)	.		(2.54)	(3.94)	(4.76)
BOD^2mean	-0.038***		-0.038**	.	Infmean	-0.005	.	-0.007
	(5.10)		(3.22)	.		(0.75)	.	(1.70)
Gini	-0.046**	-0.129***	-0.075**	-0.130***	Popgrwthdiff	-1.281***	-1.313***	-1.254***
	(2.79)	(3.34)	(3.19)	(3.36)		(5.91)	(6.71)	(6.82)
Infdiff	-0.009***		-0.009***	-0.010***	Popgrwthmean	-0.309*	.	-0.332
	(3.49)		(3.34)	(3.42)		(1.96)	.	(1.44)
Infmean	0.003		0.004	.	Sch1rydiff	0.007	-0.009	-0.002
	(0.65)		(0.85)	.		(0.4)	(0.59)	(0.14)
Popgrwthdiff	-2.143***		-2.062***	-2.094***	Sch1rymean	-0.006	.	-0.006
	(8.87)		(8.52)	(7.84)		(0.39)	.	(0.32)
Popgrwthmean	-0.524**		-0.43	.	Trade%gdpdiff	0.018***	0.051***	0.025***
	(2.66)		(1.46)	.		(6.31)	(7.72)	(6.25)
P.r.index	0.144	-0.037	0.041	-0.038	Trade%gdpmean	0.012***	.	0.017***
	(1.31)	(0.26)	(0.36)	(0.27)		(4.56)	.	(4.51)
Corrupt	-0.105	-0.064	-0.091	-0.063	Dummy variable	-0.126	.	-0.286

[21] Note: replacing the X diff and the X mean with X for the insignificant variables and the panel after dropping the insignificant variables (columns (5), (6) and (7)).

Table 3.4: Dependent variable: Annual growth

						After dropping the insignificant variables		
	(OLS)	(FE)	(RE)	(FE)		(OLS)	(FE)	(RE)
	(1)	(2)	(3)	(4)		(5)	(6)	(7)
	(0.96)	(0.41)	(0.71)	(0.40)		(0.46)	.	(0.54)
Sch1rydiff	0.015		0.017	0.012				
	(0.86)		(0.98)	(0.63)				
Sch1rymean	-0.037*		-0.034	.				
	(2.35)		(1.41)	.				
Sch2ry	0.033	0.063	0.044	0.062				
	(1.41)	(1.17)	(1.01)	(1.16)				
Trade%gdpdiff	0.018***		0.022***	0.042***				
	(5.13)		(4.87)	(4.94)				
Trade%gdpmean	0.013***		0.016***	.				
	(4.0)		(3.65)	.				
Dummy variable	-0.467	.	-0.286	.				
	(1.31)	.	(0.40)	.				
$lgdp_{pc}$		4.471***						
		(5.69)						
BOD		-1.675***						
		(5.42)						
BOD^2		0.337***						
		(4.11)						
Inf		-0.0103**						
		(3.41)						
Popgrwth		-2.111***						
		(7.90)						
Sch1ry		0.0114						
		(0.63)						
Trade%gdp		0.041***						
		(4.88)						
N	1011	1011	1011	1011	N	1464	1464	1464
R-sq	0.310	0.161		0.160	R-sq	0.187	0.104	
adj. R-sq	0.295	0.089		0.088	adj. R-sq	0.178	0.038	
rmse	3.129	2.976	2.977	2.976	rmse	3.523	3.310	3.337
R-sq (calc.)	0.3098	0.4129	0.3049	0.4124	R-sq (calc.)	0.046	0.3243	0.1815
adj. R-sq(calc.)	0.2951	0.4053	0.2900	0.4053	adj. R-sq(calc.)	0.0361	0.3211	0.1729

t statistics in parentheses * p<0.05, ** p<0.01, *** p<0.001

Table 3.5: Regression of dependent variable the rate of five years growth with the differences from the mean and the mean variables

Table 3.5: Dependent variable: rate of 5 years growth

	(OLS)	(FE)	(RE)		(OLS)	(FE)	(RE)
	(1)	(2)	(3)		(4)	(5)	(6)
Constant	-3.155	214.6	-3.623	Constant	85.17**	-233.5	209.1**
	(1.52)	(1.26)	(0.78)		(2.93)	(0.77)	(2.66)
$lgdp_{pc}$diff	23.81***		23.37***	$lgdp_{pc}$diff	20.51***		26.71***
	(17.47)		(18.18)		(9.32)		(3.35)
$lgdp_{pc}$mean	1.458***		1.536**	$lgdp_{pc}$mean	-0.066		0.436
	(6.08)		(2.87)		(0.09)		(0.22)
ρdiff	-9.583*		-10.94*	ρdiff	-20.39*		-12.76
	(1.98)		(2.29)		(2.14)		(1.12)
ρ^2diff	0.291*		0.324**	ρ^2diff	0.535*		0.344
	(2.34)		(2.64)		(2.21)		(1.18)
ρmean	-0.045***		-0.051**	ρmean	-0.098**		-0.069
	(3.71)		(2.75)		(2.96)		(1.73)
ρ^2mean	0.003***		0.003**	ρ^2mean	0.005**		0.003
	(4.08)		(2.97)		(2.93)		(1.68)
BODdiff	-17.15***		-18.39***	BODdiff	-5.900***		-7.428***
	(4.64)		(5.18)		(8.08)		(9.06)
BOD^2diff	7.430**		8.464**	BOD^2diff	1.078***		1.456***
	(2.6)		(3.11)		(6.11)		(6.63)
BODmean	0.544*		0.606	BODmean	0.290***		0.358***
	(2.57)		(1.9)		(6.61)		(4.5)
BOD^2mean	0.413		0.31	BOD^2mean	-0.094***		-0.129**
	(1.26)		(0.61)		(4.41)		(3.12)
$lgdp_{pc}$		23.20***		Ginidiff	-0.289**		-0.396***
		(17.97)			(3.27)		(4.32)
ρ		-11.53*		Ginimean	-0.197***		-0.266*
		(2.36)			(3.92)		(2.14)
ρ^2		0.338**		Infdiff	-0.041***		-0.035***
		(2.7)			(3.44)		(4.29)
BOD		-18.81***		Infmean	0.024		0.029
		(5.25)			(1.58)		(1.72)
BOD^2		8.816**		Popgrwthdiff	-5.891***		-4.134***
		(3.21)			(7.53)		(5.79)
				Popgrwthmean	-2.341***		-1.519
					(3.45)		(0.92)

Table 3.5: Dependent variable: rate of 5 years growth

	(OLS)	(FE)	(RE)		(OLS)	(FE)	(RE)
	(1)	(2)	(3)		(4)	(5)	(6)
				P.r.indexdiff	0.557		0.014
					(1.42)		(0.04)
				P.r.indexmean	0.994*		1.258
					(2.04)		(1.28)
				Corruptdiff	0.0553		0.259
					(0.11)		(0.61)
				Corruptmean	-0.989*		-2.575*
					(2.07)		(2.22)
				Sch1rydiff	0.092		0.095
					(1.55)		(1.94)
				Sch1rymean	-0.134***		-0.148
					(3.43)		(1.52)
				Sch2rydiff	-0.013		0.277
					(0.12)		(1.91)
				Sch2rymean	-0.608*		-1.838*
					(2.11)		(2.34)
				Trade%gdpdiff	0.075***		0.084***
					(6.63)		(5.18)
				Trade%gdpmean	0.045***		0.054***
					(4.35)		(3.38)
				Dummy variable	-2.591*	.	-5.025
					(2.13)	.	(1.65)
				$lgdp_{pc}$		31.16***	
						(14.19)	
				ρ		4.72	
						(0.43)	
				$ρ^2$		-9.817	
						(0.35)	
				BOD		-7.496***	
						(9.94)	
				BOD^2		1.426***	
						(7.64)	
				Gini		-0.439***	
						(4.08)	
				Inf		-0.069***	
						(5.58)	
				Popgrwth		-5.988***	
						(8.32)	
				P.r.index		0.255	
						(0.71)	

Table 3.5: Dependent variable: rate of 5 years growth

	(OLS)	(FE)	(RE)		(OLS)	(FE)	(RE)
	(1)	(2)	(3)		(4)	(5)	(6)
				Corruption		0.190	
						(0.46)	
				Sch1ry		0.0375	
						(0.81)	
				Sch2ry		0.264	
						(1.84)	
				Trade%gdp		0.086***	
						(3.91)	
N	2507	2507	2507	N	1005	1005	1005
R-sq	0.18	0.136		R-sq	0.485	0.360	
adj. R-sq	0.177	0.100		adj. R-sq	0.471	0.306	
rmse	13.74	12.68	12.69	rmse	9.476	7.571	8.174
R-sq(Calculated)	0.1803	0.3223	0.1801	R-sq(Calculated)	0.4853	0.6346	0.4669
adj. R-sq(Calculated)	0.1769	0.3209	0.1768	adj. R-sq(Calculated)	0.4678	0.6297	0.4522

t statistics in parentheses * p<0.05, ** p<0.01, *** p<0.001

Table 3.6: Regression of dependent variable rate of five years growth with an amended specification[22] from table 3.5

Table 3.6: Dependent variable: rate of five years growth								
						After dropping the insignificant variables		
	(OLS)	(FE)	(RE)	(FE)		(OLS)	(FE)	(RE)
	(1)	(2)	(3)	(4)		(5)	(6)	(7)
Constant	38.82***	-233.5	20.73	-4.173	Constant	6.744	11.37***	5.483
	(4.06)	(0.77)	(1.33)	(0.29)		(1.72)	(31.33)	(0.74)
$lgdp_{pc}diff$	19.79***		25.83***	31.16***	$lgdp_{pc}diff$	6.051***	4.679***	2.835*
	(9.58)		(13.89)	(14.19)		(3.76)	(3.44)	(2.24)
$lgdp_{pc}mean$	-0.512		-1.397	.	$lgdp_{pc}mean$	-1.098**	.	-0.918
	(0.83)		(1.36)	.		(2.82)	.	(1.17)
ρdiff	-20.14*		-12.62	4.72	ρdiff	20.98*	31.53***	23.13**
	(2.21)		(1.11)	(0.43)		(2.58)	(4.52)	(3.04)
ρ^2diff	0.533*		0.343	-0.0982	ρ^2diff	-0.525*	-0.786***	-0.581**
	(2.3)		(1.17)	(0.35)		(2.57)	(4.44)	(3.02)
ρmean	-0.101**		-0.0751	.	ρmean	0.051	.	0.068*
	(3.19)		(1.90)	.		(1.87)	.	(2.26)
ρ^2mean	0.005**		0.004	.	ρ^2mean	-0.003	.	-0.003*
	(3.17)		(1.87)	.		(1.83)	.	(2.18)
BODdiff	-5.687***		-7.101***	-7.496***	BODdiff	-1.603***	-1.363***	-1.231***
	(7.97)		(8.72)	(9.94)		(6.34)	(4.51)	(4.17)
BOD^2diff	1.005***		1.356***	1.426***	BOD^2diff	0.160***	0.177**	0.133**
	(5.94)		(6.22)	(7.64)		(3.75)	(2.97)	(3.07)
BODmean	0.286***		0.373***	.	BODmean	0.056***	.	0.015
	(6.66)		(4.74)	.		(3.81)	.	(0.41)
BOD^2mean	-0.088***		-0.128**	.	BOD^2mean	-0.005	.	0.002
	(4.34)		(3.13)	.		(1.16)	.	(0.31)
Gini	-0.219***	-0.439***	-0.365***	-0.439***	Infdiff	-0.068**	-0.098***	-0.062***
	(4.37)	(4.08)	(4.58)	(4.08)		(2.93)	(7.21)	(6.46)
Infdiff	-0.039***		-0.035***	-0.069***	Infmean	-0.0109	.	-0.0163
	(3.46)		(4.24)	(5.58)		(0.44)	.	(0.95)
Infmean	0.026		0.044**	.	Popgrwthdiff	0.458	0.840	0.808
	(1.72)		(2.78)	.		(0.67)	(1.51)	(1.41)

[22] Note: replacing the X diff and the X mean with X for the insignificant variables and the panel after dropping the insignificant variables (columns (5), (6) and (7)).

Table 3.6: Dependent variable: rate of five years growth

						After dropping the insignificant variables		
	(OLS)	(FE)	(RE)	(FE)		(OLS)	(FE)	(RE)
	(1)	(2)	(3)	(4)		(5)	(6)	(7)
Popgrwthdiff	-5.989***		-4.347***	-5.988***	Popgrwthmean	0.047	.	0.901
	(7.97)		(6.13)	(8.32)		(0.08)	.	(0.8)
Popgrwthmean	-2.211***		-0.768	.	Sch1rydiff	-0.091	0.042	-0.047
	(3.37)		(0.53)	.		(1.33)	(1.1)	(1.19)
P.r.index	0.857*	0.255	0.26	0.255	Sch1rymean	0.097**	.	0.095
	(2.52)	(0.71)	(0.74)	(0.71)		(2.6)	.	(1.22)
Corruption	-0.371	0.19	-0.034	0.19	Trade%gdpdiff	0.089***	0.072***	0.098***
	(1.06)	(0.46)	(0.08)	(0.46)		(8.56)	(4.29)	(6.86)
Sch1rydiff	0.091		0.095	0.038	Trade%gdpmean	0.056***	.	0.062***
	(1.6)		(1.95)	(0.81)		(5.76)	.	(4.13)
Sch1rymean	-0.122**		-0.108	.	Dummy variable	-1.805	.	-3.9
	(3.25)		(1.16)	.		(1.85)	.	(1.59)
Sch2ry	-0.122	0.264	0.154	0.264				
	(1.50)	(1.84)	(1.16)	(1.84)				
Trade%gdpdiff	0.073***		0.079***	0.086***				
	(6.59)		(4.97)	(3.91)				
Trade%gdpmean	0.044***		0.051**	.				
	(4.17)		(3.19)	.				
Dummy variable	-2.526*	.	-5.191	.				
	(2.11)	.	(1.78)	.				
$lgdp_{pc}$		31.16***						
		(14.19)						
ρ		4.72						
		(0.43)						
ρ^2		-9.813						
		(0.35)						
BOD		-7.496***						
		(9.94)						
BOD^2		1.426***						
		(7.64)						
Inf		-0.069***						
		(5.58)						
popgrwth		-5.988***						
		(8.32)						
Sch1ry		0.037						
		(0.81)						
Trade%gdp		0.086***						
		(3.91)						

Table 3.6: Dependent variable: rate of five years growth

						After dropping the insignificant variables		
	(OLS)	(FE)	(RE)	(FE)		(OLS)	(FE)	(RE)
	(1)	(2)	(3)	(4)		(5)	(6)	(7)
N	1005	1005	1005	1005	N	1683	1683	1683
R-sq	0.482	0.360		0.319	R-sq	0.228	0.078	
adj. R-sq	0.470	0.306		0.310	rmse	12.21	10.07	10.71
rmse	9.485	7.571	8.214	7.805	adj. R-sq	0.219	0.020	
R-sq(calc.)	0.4822	0.6346	0.4590	0.64577	R-sq(calc.)	0.2281	0.42758	0.2173
adj. R-sq(calc.)	0.4701	0.6297	0.4463	0.64112	adj. R-sq(calc.)	0.2193	0.42450	0.2084

t statistics in parentheses * p<0.05, ** p<0.01, *** p<0.001

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Appendix 3.I

Table 3.I.1

The dependent variable LGDP per capita

. test ρdiff= ρmean
ρdiff - ρmean = 0
F(1, 1474) = 22.49
Prob > F = 0.0000

. test ρsqdiff=ρsqmean
ρsqdiff - ρsqmean = 0
F(1, 1474) = 22.35
Prob > F = 0.0000

. test boddiff =bodmean
boddiff - bodmean = 0
F(1, 1474) = 2.37
Prob > F = 0.1237

. test bod^2diff = bod^2mean
bod^2diff - bod^2mean= 0
F(1, 1474) = 0.24
Prob > F = 0.6236

. test ginidiff = ginimean
ginidiff - ginimean = 0
F(1, 1474) = 1.40
Prob > F = 0.2372

. test infdiff= infmean
infdiff - infmean = 0
F(1, 1474) = 5.54
Prob > F = 0.0187

. test popgrwthdiff= popgrwthmean
popgrwthdiff - popgrwthmean = 0
F(1, 1474) = 7.42
Prob > F = 0.0065

. test prindexdiff= prindexmean
prindexdiff - prindexmean = 0
F(1, 1474) = 345.21
Prob > F = 0.0000

. test corruptdiff= corruptmean
corruptdiff - corruptmean = 0
F(1, 1474) = 262.77
Prob > F = 0.0000

. test sch1rydiff= sch1rymean
sch1rydiff - sch1rymean = 0
F(1, 1474) = 1.02
Prob > F = 0.3124

sch2rydiff =sch2rymean
sch2rydiff - sch2rymean = 0
F(1, 1474) = 0.73
Prob > F = 0.3919

tradeofgdpdiff= tradeofgdpmean
tradeofgdpdiff - tradeofgdpmean
F(1, 1474) = 0.06
Prob > F = 0.8101

Table 3.I.2

The dependent variable: Annual growth

. test lgdppcdiff =lgdppcmean
lgdppcdiff - lgdppcmean = 0
F(1, 983) = 20.18
Prob > F = 0.0000

. test ρdiff= ρmean
ρdiff - ρmean = 0
F(1, 983) = 0.14
Prob > F = 0.9625

. test ρ^2diff= ρ^2mean
ρ^2diff - ρ^2mean = 0
F(1, 983) = 0.13
Prob > F = 0.9716

. test boddiff =bodmean
boddiff - bodmean = 0
F(1, 983) = 42.84
Prob > F = 0.0000

. test bod^2diff = bod^2mean
bod^2diff – bod^2mean = 0
F(1, 983) = 30.43
Prob > F = 0.0000

. test ginidiff = ginimean
ginidiff - ginimean = 0
F(1, 983) = 3.90
Prob > F = 0.0487

. test infdiff= infmean
infdiff - infmean = 0
F(1, 983) = 19.98
Prob > F = 0.0000

. test popgrwthdiff= popgrwthmean
popgrwthdiff - popgrwthmean = 0
F(1, 983) = 29.09
Prob > F = 0.0000

. test prindexdiff= prindexmean
prindexdiff - prindexmean = 0
F(1, 983) = 1.60
Prob > F = 0.2057

. test corruptdiff= corruptmean
corruptdiff - corruptmean = 0
F(1, 983) = 0.19
Prob > F = 0.6599

. test sch1rydiff= sch1rymean
sch1rydiff - sch1rymean = 0
F(1, 983) = 6.27
Prob > F = 0.0124

. test sch2rydiff =sch2rymean
sch2rydiff - sch2rymean = 0
F(1, 983) = 0.64
Prob > F = 0.4224

. test tradeofgdpdiff= tradeofgdpmean
tradeofgdpdiff - tradeofgdpmean
F(1, 983) = 4.89
Prob > F = 0.0272

Table 3.I.3

The dependent variable: Rate of 5 years growth

. test lgdppcdiff =lgdppcmean
lgdppcdiff - lgdppcmean = 0
F(1, 977) = 82.92
Prob > F = 0.0000

. test ρdiff= ρmean
ρdiff - ρmean = 0
F(1, 977) = 4.56
Prob > F = 0.0330

. test ρ^2diff= ρ^2mean
ρ^2diff-ρ^2mean = 0
F(1, 977) = 4.85
Prob > F = 0.0279

. test boddiff =bodmean
boddiff - bodmean = 0
F(1, 977) = 65.04
Prob > F = 0.0000

. test bod^2diff = bod^2mean
bod^2diff – bod^2mean = 0
F(1, 977) = 35.96
Prob > F = 0.0000

. test ginidiff = ginimean
ginidiff - ginimean = 0
F(1, 977) = 1.25
Prob > F = 0.2638

. test infdiff= infmean
infdiff - infmean = 0
F(1, 977) = 40.30
Prob > F = 0.0000

. test popgrwthdiff= popgrwthmean
popgrwthdiff - popgrwthmean = 0
F(1, 977) = 15.92
Prob > F = 0.0001

. test prindexdiff= prindexmean
prindexdiff - prindexmean = 0
F(1, 977) = 0.63
Prob > F = 0.4259

. test corruptdiff= corruptmean
corruptdiff - corruptmean = 0
F(1, 977) = 2.45
Prob > F = 0.1176

. test sch1rydiff= sch1rymean
sch1rydiff - sch1rymean = 0
F(1, 977) = 12.79
Prob > F = 0.0004

. test sch2rydiff =sch2rymean
sch2rydiff - sch2rymean = 0
F(1, 977) = 2.92
Prob > F = 0.0881

. test tradeofgdpdiff= tradeofgdpmean
tradeofgdpdiff - tradeofgdpmean
F(1, 977) = 11.31
Prob > F = 0.0008

Chapter 4

Effect of Socio Economic Productivity on Water Withdrawal

4.1 Introduction

Humanity's activities are affecting the water cycle and the weather directly by unmanaged consumption and the withdrawal of different economic sectors, and by the indirect effect of rapid industrialization and urbanization that has invaded the forests and disturbed the ecosystem. This is in addition to the global warmth due to gas emissions. Although water is a renewable resource, its availability is directly connected to geographical features, the bio- physical situations in different regions. Also technology affects the water withdrawal and impacts on managing the resources within the context of scarcity. Different hypotheses have been put forward concerning the relationship between water and its effect on different economic sectors. Several questions can be asked here, for example does a higher water withdrawal for one sector mean that this sector is adding more to the GDP or is it a sunk cost compared with the benefits to the economy? Do social factors affect withdrawing water more than economic factors or are they both impacting? In chapter 2, we modelled the effect of the ratio of water utilization and water quality on the economic growth, in this chapter we aim to answer the above mentioned questions and to shed light on different socio- economic factors that affect water withdrawal in different economic sectors.

4.2 Factors affecting water withdrawal

The sustainable development definition was introduced by the Brundland Commission[23] report 'Our Common Future' (1987, p.43) *"Sustainable development is development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs"* integrated sustainability with the natural environment. It emphasized the relationship between human activities, social aspects and the environment (WCED – CMED, 1987). In 1995 the World Bank published the estimates of the natural wealth; these estimates embody the sum of physical capital, human capital and natural capital and finally the social

[23] The World Commission on Environment and Development (WCED) held by the United Nations in 1987 to unite international society to address the sustainable development, resulted in a report (Our Common Future). The report was named the Brundtland Report in recognition of the chairman of the WCED, Gro Harlem Brundtland.

capital. Social capital stands for institutions and infrastructure. This estimation of natural capital that enters the equality can be a part of the assessment of agricultural land, forests, and minerals.

The demand for water arises from different major sectors, agriculture, production of energy, industrial uses and the domestic sector. With respect to economic growth and water resource allocation, the factors that affect the withdrawal of water for one sector more than another can be economic or social. There is relatively little literature that discusses these factors and their effect on the ecosystem. As a start, water can be both a social and an economic good (Gleick *et a.l.*, 2002), Although the Dublin and Rio conferences declared water as an economic good and addressed the management of water resources as an economic process, they did not gave an idea as to how efficient water management as an economic and social good can be achieved (Gleick *et al*., 2002).

Agriculture is the main contributor to socio-economic factors, whether by its contribution in the GDP of most of the developing nations or due its provision of food around the world. Due to the vast scale of the relevant literature we focus our review mainly on recent contributions by economists. Prior to the twentieth century, nations used to cultivate lands to increase their crops and animal production. At the end of the twentieth century, technology and scientific advancements played its main role in increasing productivity in order to meet the growing population that has doubled from 2.5 billion in 1950 to 6.0 billion in 2000. At the same time, water for irrigation consumes the highest amount of withdrawal. Not all the global agriculture depends on irrigated water, a great portion, which accounts for 80% of global cropland, is rain fed. Moreover, about 60-70% of crops are produced by rain fed lands (Falkenmark and Rockström, 2004).

Throughout history, humans adopted agriculture as a priority for living, Diamond (1997) mentioned the hunters and gatherers who did not play a part in supporting food for others. With agriculture, humans started to produce food for society, and here started the specialization where the economy is built on food producers and non-food producers specialists that were fed by food producers. In modern history, the social economic interaction is based on three basic sectors agricultural, industrial and the service sectors.

In the transition and the emerging economies, the industrial and the services sectors are developing and contribute more and more to the GDP of the country accompanied by an increasing demand for water. Gleick (2004) studied the interdependent relationship between water use and the economy taking California - United States, as a targeted point of study and concluded that *"There are gross disparities in the "economic productivity" of water use. Even modest reallocations of water from one sector of our economy to another can produce significant changes in job availability and gross state product, but such reallocations must take account of regional economic priorities, job displacement and retraining issues, equity, and environmental side-effects"*(p.1).

Given water is a constrained resource, it is important to shed light on the factors that affect water allocation and withdrawal between different economic sectors within the business-economic context, which can be conceptualized by using indicators that stand for employment, industrial and agricultural productivity that have an impact on the socio-economic and ecological infrastructure, and which interact to lead society towards a long-term viable growth.

4.3 Agriculture, food production and food demand

With the population increase, the demand is increasing for agriculture and food. *"Agriculture takes the highest share among water user sectors in low-and middle income countries"* Pereira *et al.* (2002, p.10). Global water withdrawal for irrigation purposes accounts for 90% of water consumption and more than 40% of crops are produced from irrigated lands, although irrigated areas cover less than a fifth of cropped areas, they still produce about 45% of the world's crops (Döll and Siebert, 2002). Döll and Siebert doubted the availability of water to meet the needs of the projected population increase that is given by the United Nations population projections of 1.5-2 billion people by 2025.

The demand for food is unlike almost any other demand for goods, it is inelastic. Weisdorf (2003) combines exogenously improving food production with food consumption to model the abrupt emergence of a non-food-producing sector, which he identifies with the creation of food surpluses under agriculture. Food demand enhanced the production of food. That created advancements in food technology and the emergence of non-food specialists. Therefore the advancements in agriculture led to organizational changes that shifted the production to establish the impact of industry and led to the rising importance of industry as a component of the GDP. Weisdorf (2003) elucidated the idea that the agricultural sector enhanced the role of the non-food specialists. These ideas and explanations imply something more, that water withdrawal for the agricultural sector has a spill over effect enhancing water withdrawal for other sectors in the economy.

Water and land are the main inputs into agriculture, but if land is the main factor of production, the economic activity will become more costly. Several factors make the land use costly. The ecosystem is controlled by human presence, therefore population growth, industrialization and urbanization, adding to human activities over the last decades has affected land surface features; mainly through land adaptation, that is by shifting from agriculture to other economic activities, there has been a deterioration and alteration of the ecosystem, (Vitousek *et al.*, 1997). Nevertheless, the green revolution which is a consequence of technological advancements that contributed to solving the Asian food crisis in the 1960's increased the awareness of the importance of the agricultural sector. Other factors that impact on land use, agricultural productivity and cost are climate change and climate policy.

Discussing water as an economic and social input in economic growth and in development sheds light on the economic and social structure of the society. The shift in population and structure of demography created a shift in the alignment of the different economic sectors. This is reflected in employment shifting from the agricultural sector into the industrial and services sectors, which contributed to growing urbanization. This facilitated advancements in agriculture by the practical and efficient use of physical and human capital. In general, the endogenous growth theory deals with the quality of inputs and the contribution of technological advancements. Technology in its part has a spill over effect for different economic sectors that leads to changes in the allocation and shifts in the labour force between different sectors (Cypher and Dietz, 2009, pp. 270).

Concerning employment, the capital stock growth that shapes the structural change of the economy, can influence the labour force that is allocated between different economic sectors. It is well known that many small countries are growing fast in terms of industrial employment. Policy reforms and openness of trade in newly emerged economies are facilitating this. Some of the industrial employment shifts away from agriculture into service employment. Specialization plays its part in employment allocation to different sectors of the economy (Desmet and Rossi-Hansberg, 2009). Desmet and Rossi-Hansberg noticed that large countries grow faster with respect to service employment than the smaller ones, and consequently suffer from localised land congestion due to spatial concentration.

4.4 Methodology of factors of production

In discussing economic growth and the allocation of water as an input in the economic sectors, productivity is driven by the inputs in the economy. Employment intensity in different sectors contributes to the GDP growth. The previous literature illustrated this by providing an insight about the relationship between productivity and employment in different economic sectors.

Taking water as an economic and social good, in the economics of production theory the demand for water as an input can be considered as a demand for a social final good that is consumable for daily activities and life necessities such as drinking or any other household activities, or it is demanded as an input in production for different sectors in the economy. Water as an economic good is priced by the interaction of supply and the demand of consumers for that input. Producers in the economy use water as an input and their demand for water is a derived demand. This demand in itself is called derived due to its contribution or its virtual value in the final form of the commodities produced in different sectors of the economy (Berrittella *et al.*, 2007; Hanemann, 1997). Of course the demand is derived from the tastes and preferences of the user or the consumer of water, in other words, the demand is governed by the consumer's utility function, and of course the profits function for firms, as well as natural resources.

Following Hanemann (1997) who incorporated the *water requirements approach* to forecast the industrial water use, we are going to employ this approach in our study on the effects of different socio economic factors on water demand and water withdrawal per capita in different economic sectors. The water withdrawal depends on the scale of production or the output produced in an industry and the demand for water as an input. The scale of production is measured in terms of physical units of output or the labour force used in the production process. In different kinds of industries, this can be expressed as:

$R_i = f(Y_i)$

$R_i = g(L_i)$

R_i = water input for the i^{th} industry in the economic sector.

Y_i = the output or the production in the i^{th} industry in the economic sector.

L_i = employment as a factor of production in the production process.

Assuming a constant factor of proportionality, then:

$$R_i = \alpha_i Y_i \quad (4.1)$$

$$R_i = \beta_i L_i \quad (4.2)$$

Where

α_i = water intake per unit of output in the i^{th} type of industry

β_i = water intake per unit of employee in the i^{th} type of industry

Both α_i and β_i are constants depending on the sector or industry, *i*, but are fixed over all the production processes in an industry. To further illustrate, the scale of proportionality in water intake the two equations (4.1) and (4.2) can be rewritten as

$$R_i = \alpha_i Y_i^{\gamma} \quad (4.3)$$

$$R_i = \beta_i E_i^{\gamma} \quad (4.4)$$

γ in this case is a criteria for the proportionality of scale (scale of production) and depends on the industry or the sector the water is withdrawn for. Water use increases less than proportionately with scale of production if $\gamma < 1$, and more than proportionately if $\gamma > 1$.

The restriction of these formulas is that the parameters α_i, β_i and γ are assumed constant across different industries and firms in the sector. Another restriction is that it ignores the cost of water as an input in the industry. To overcome these restrictions and to derive the input demand functions we are going to employ a method taking a profit maximizing firm in any industry in the different economic sectors as a sample of analysis. We assume that (i) water withdrawal varies with the industry in different sectors of the economy, (ii) the firm is profit maximizing and it maximizes revenue from outputs subject to costs. We are going to highlight the input demand by the single firm to model the optimization by the firm. The firm produces its outputs from various combinations of inputs. Suppose the firm uses N inputs, one of which is the water input, the production cost of the firm can be expressed by:

$$C = a_1 x_1 + \dots\dots + a_N x_N \equiv \sum_{k=1}^{N} a_K x_K \tag{4.5}$$

Where x_k is the amount of input used by the firm such that k=1,2,…..,N, and a_k is the price of the kth input, if (p) is the selling price of output, then

$$\pi = Py - \sum_{k=1}^{N} a_k x_k \tag{4.6}$$

Where π is profit, taking y as the output of production assuming a constant return to scale of technology, this can be represented as a function of inputs:

$$y = f(x_1, x_2, \dots, x_N), f_{x_k} > 0 \tag{4.7}$$

We now incorporate the production technology that is available for the firm. In economics, the Cobb–Douglas functional form of production functions is frequently used to describe the relationship between outputs and inputs. For that, factors of production in the economy can be expressed in an equation of production output y can be expressed as:

$$y = Ax_1^{\beta_1} x_2^{\beta_2} ....x_N^{\beta_N} \tag{4.8}$$

Where:

- A>0, β_k>0, k=1,2,……,N
- y = total production (the monetary value at constant price of all goods produced in a year)
- β's are the output elasticities of inputs. These values are constants determined by available technology. These elasticities determine how the output in the economy is changing with the inputs of production.

The firm is assumed to maximize profits. Then assuming a long- run profit maximization where all the N inputs are variable and the firm's own decision is to select the optimal input variables $(x_1....x_N)$ in order to maximize

$$\pi = pf(x_1.....x_N) - \sum a_k x_k \tag{4.9}$$

Assuming a long run profit maximization where all the N inputs are variables and the firm's own decision is to select the input variables $(x_1....x_N)$, the aim for the firm is to choose the optimal input levels given the input prices $(a_1, a_2,......,a_N)$ and the price of the output *p*. Due to this behavioral rule, the optimal choice of input can be given by the function

$$x_k = h^k(a_1, a_2,.....,a_N, p), \quad k = 1.....N \tag{4.10}$$

This is a long run unconditional input demand function. The derivatives of this function embody the responsiveness of unconditional demand for an input x_i to its price, a_i, as well as its sensitivity to the output price, *p*. The optimal level of output the firm provides is

$$y = f[h^1(a_1.....a_N, p),.........., h^N(a_1.....a_N, p)] = y(a_1......a_N, p) \tag{4.11}$$

Therefore, the profit due to the optimal level of output is given by

$$\pi = py(a_1.....a_N, p) - \sum a_k h^k (a_1.....a_N, p) = \pi(a_1.....a_N, p) \tag{4.12}$$

Considering the Cobb-Douglas production function, profit can be written as given

$$y = Ax_1^{\beta_1} x_2^{\beta_2} ....x_N^{\beta_N} \text{ , where } A > 0, \beta_k > 0, k = 1,......,N \tag{4.13}$$

Profit can be written as:

$$\pi = p.Ax_1^{\beta_1} x_2^{\beta_2} .....x_N^{\beta_N} - \sum a_k h^k (a_1.....a_N, p) \tag{4.14}$$

From Henderson and Quandt (1980, p.80) for simplicity we reduce the number of inputs to just two inputs, and defining x_1 as the water input and x_2 as representing other combined inputs, then:

$$\pi = p.Ax_1^{\beta_1} x_2^{\beta_2} - \sum_{k=1}^{2} a_k h^k (a_1, a_2, p) \tag{4.15}$$

We can write $\pi = pAx_1^{\beta_1} x_2^{\beta_2} - a_1 x_1 - a_2 x_2$ (4.16)

Set the partial derivatives equal to zero:

$$\frac{\partial \pi}{\partial x_1} = pA\beta_1 x_1^{\beta_1 - 1} x_2^{\beta_2} - a_1 = 0 \tag{4.17}$$

$$\frac{\partial \pi}{\partial x_2} = pA\beta_2 x_2^{\beta_2 - 1} x_1^{\beta_1} - a_2 = 0 \tag{4.18}$$

Solving equations for each of the factor amounts, we obtain the inputs demand functions as functions of the factor price as well as the output price

$$x_1 = h^1(a_1, a_2, p) = (Ap)^{\frac{1}{1-\beta_1-\beta_2}} \left(\frac{\beta_1}{a_1}\right)^{\frac{1-\beta_2}{1-\beta_1-\beta_2}} \left(\frac{\beta_2}{a_2}\right)^{\frac{\beta_2}{1-\beta_1-\beta_2}} \tag{4.19}$$

$$x_2 = h^2(a_1, a_2, p) = (Ap)^{\frac{1}{1-\beta_1-\beta_2}} \left(\frac{\beta_1}{a_1}\right)^{\frac{\beta_1}{1-\beta_1-\beta_2}} \left(\frac{\beta_2}{a_2}\right)^{\frac{1-\beta_1}{1-\beta_1-\beta_2}} \tag{4.20}$$

The demand for each input will decrease as the input costs a_1 and a_2 increases, and will increase as *p*, the price of output increases. To make the input demand functions linear we double-log the equations in the form

$$\ln x_1(a_1, a_2, p) = \alpha_0 + \alpha_1 \ln p + \alpha_2 \ln a_1 + \alpha_3 \ln a_2 \tag{4.21}$$

Where

$\alpha_0 = [\ln A + (1-\beta_2)\ln\beta_1 + \beta_2 \ln\beta_2] \;/(1-\beta_1-\beta_2)$

$\alpha_1 = 1/(1-\beta_1-\beta_2)$

$\alpha_2 = (\beta_2 - 1)/(1-\beta_1-\beta_2)$

$\alpha_3 = (-\beta_2)/(1-\beta_1-\beta_2)$

The parameters $\alpha_1 > 1, \alpha_2 < -1$ and $\alpha_3 < -1$

Also, the same for x_2

$$\ln x_2(a_1, a_2, p) = \lambda_0 + \lambda_1 \ln p + \lambda_2 \ln a_1 + \lambda_3 \ln a_2 \tag{4.22}$$

Where

$\lambda_0 = [\ln A + (1-\beta_1)\ln\beta_1 + \beta_1 \ln\beta_2]/(1-\beta_1-\beta_2)$

$\lambda_1 = 1/(1-\beta_1-\beta_2)$

$\lambda_2 = (\beta_1 - 1)/(1-\beta_1-\beta_2)$

$\lambda_3 = (-\beta_1)/(1-\beta_1-\beta_2)$

Where $\lambda_1 > 1, \lambda_2 < -1, \lambda_3 < -1$

The restrictions of parameters $\alpha's$ and $\lambda's$ are a consequence of restrictions on the parameters of Cobb- Douglas which are A and β's, therefore the relationship between different parameters can be written as:

$$\alpha_2 + \alpha_3 = \lambda_2 + \lambda_3 = -\alpha_1 = -\lambda_1, -1 < \alpha_3/\alpha_2 < 0, -1 < \lambda_3/\lambda_1 < 0$$

$$-1 < (\alpha_3 + \lambda_3)/\alpha_1 < 0$$

The intercept parameters α_0 and λ_0 are not restricted because for: $0 < A \leq 1 \Leftrightarrow (\alpha_0 < 0 \wedge \lambda_0 < 0)$[24]

Also, $A > 1 \Leftrightarrow (\alpha_0 \in R \wedge \lambda_0 \in R)$

The input price elasticity of supply can be positive or negative depending on whether the input is a normal input or inferior one.

To integrate the theory with our model from equations (4.19) and (4.20). The essential point is that demand for any factor of production will depend upon both the price of the produced good, and the price of all factors of production. It will also depend upon the parameters of the production function which are in part determined by technology. These in turn can be linked to socio-economic variables. For example, let X_1 represent the demand for input water. This now depends upon the efficiency parameters from the Cobb Douglas function, input prices and the product price. We do not have data on these and instead we model them indirectly. For example, as GDP per capita rises so efficiency tends to increase as people become aware of more sophisticated techniques. On this basis we might expect the demand for water to fall. However, as countries tend to become wealthier so the demand for non-essential goods increases. This will drive up, the price of non-agricultural output. This will tend to increase water withdrawal for non-agricultural output. An example would be more water demanded to households. In the following section we will describe in more detail the exact equations we will be estimating.

[24] $\wedge$ is logical conjunction, can stands for and or/and meet, e.g. The statement $A \wedge B$ is true if A and B are both true; else it is false, source (Weisstein, Eric W. "Conjunction." From MathWorld--A Wolfram Web Resource. http://mathworld.wolfram.com/Conjunction.html).

4.5 Empirical analysis

4.5.1 Data and statistics

Longo and York (2009) investigated the endogenous agricultural water's and the non- agricultural water's effects on the industrialized modern nature of agriculture. This depends on modern technological advancement that affected the agricultural water use over several decades. The advancement in this sector is directly related to food demand that increases as population increases. This study investigates, in depth, the interaction between humans and the environment and can be useful to monitor the direct effect on water withdrawal from agricultural and the non- agricultural sectors of different national economic variables that act as a sensor for economic development and growth. According to Longo and York, water consumption in one sector is related to that in another sector. This is also consistent with economic theory, which would argue that total water demand from all sectors and purposes is equated to supply by price. Therefore, the three stage least squares is a suitable method for our empirical analysis.

In terms of data requirements for the present analysis, we are taking into account the differences between different countries in income, population and socio economic development with respect to the issue of water scarcity. The different sectors, the agricultural, the industrial and the domestic uses for water are competing for a finite water resource supply.

4.5.2 The analysis

It is clear from equations 4.3 and 4.4, that we assume that the water withdrawal is likely to increase with the output in the economy. The empirical analysis is a translation of this equation and analyses the different factors in the economy that may affect water withdrawal per capita. We conducted the analysis with pooled times series and cross section data for a 174 countries for the period covering 1970-2009. In our analysis we used three stages least square to analyse the relationship between different variables at different levels, we estimate the two equations for the analysis, one for the agricultural water withdrawal and the second for non- agricultural water withdrawal. Looking at equations (4.19) and (4.20), we have input demand as a nonlinear function of output price, the input price of water and other inputs in industry. We rewrite the equations in a more general form as:

$$x = f(p, a_1, a_2) \tag{4.23}$$

We will not estimate this directly, but estimate a regression with independent variables which stand as proxies for p, a_1 and a_2, these will include

First equation:

A- Agricultural water withdrawal= f(Non-Agricultural water withdrawal, Water resources/Land, arable land per capita, Agriculture% in GDP, Trade as % of GDP, Agricultural employment, population density, GDP Per Capita, Food production index, Dummy variable for developing countries)

Second equation:

B- Non Agricultural Water withdrawal= f(Agricultural water withdrawal, Water resources/Land, Industrial % in GDP, Services % in GDP, Trade as % of GDP, Non-agricultural employment, Population density, GDP Per Capita, Dummy variable for developing countries)

The rationale for these has already been discussed within the context of the literature review. The dependence and the allocation of water withdrawal for different sectors is represented in figure (4.1). The variables themselves are defined in Table (4.1). We constructed our model in a way that the two endogenous variables, the agricultural water withdrawal and the non-agricultural water withdrawal are interdependent, because there would be competitiveness in water withdrawal for one sector on the account of another sector. Different exogenous variables that affect both endogenous variables at the same time or affecting water withdrawal for different sectors separately.

The first equation contains the variables that affect the water withdrawal for irrigation purposes, in other words for the agricultural sector. The variables we used for the analysis of agricultural water withdrawal included the non- agricultural water withdrawal. The remaining variables in this equation are related directly to agriculture such as the water resources per land unit to see the effect on water withdrawal for irrigation purposes on water resources which are available for all the economic sectors. Furthermore, Calzadilla *et al.* (2011, p.10) considered the value of irrigated water as a part of the value of the land, for the fact that land is considered *"as a factor of production in national accounts"* following the fact that *"The ground, including the soil covering and any associated surface waters, over which ownership rights are enforced"* (United Nations 1993, p.391). This therefore reflects supply side constraints. For that purpose, the renewable water resources by the land area represent the amount available for different economic sectors. We also used the arable land per capita since this factor is important in the production of food and represents a potential factor reflecting demand. A further demand side factor is the share of agriculture input as a percentage of GDP. Agricultural employment was also included as a further indicator of demand side variables, since employment intensity in different sectors contributes to the GDP growth, for instance, agricultural production may affect the efficiency with which water is used. Finally we added the food production index as a further demand side variable, and as a proxy for the inputs of agriculture in economics and since the relation of water use is interconnected between different sectors, food is includable due to its relevant part as a good in trade, services through distribution channels, and industry through food industry like canning, food transforming…etc. Food is important on many dimensions. In 1996, Rome's World Food Summit emphasised the importance of enhancing the economic progress in agriculture is in order to increase the income and raise the food supply for the poor. Hence it is important we capture its full effects.

In the second equation we used the non-agricultural water withdrawal as the dependent variable. The right hand side variables that affect this water use include non-agricultural employment, the industrial and the service sectors as a percentage of GDP, in addition to the water per land unit is added to see the effect on water use for the non-agricultural sector of water resources. Employment in the different sectors is added, reflecting the industrial structure of the economy, for the fact that the capital stock growth that shapes the structure of the economy, can shape the labour capacity that is allocated between different economic sectors. As for the variables that are common in both equations these included (i) trade as a percentage of GDP to represent the openness in the economy and globalization, (ii) the population density considered by the UNESCO (2003) as a major factor impacting on the usage of water. These relationships are also summarised in Figure 4.1.

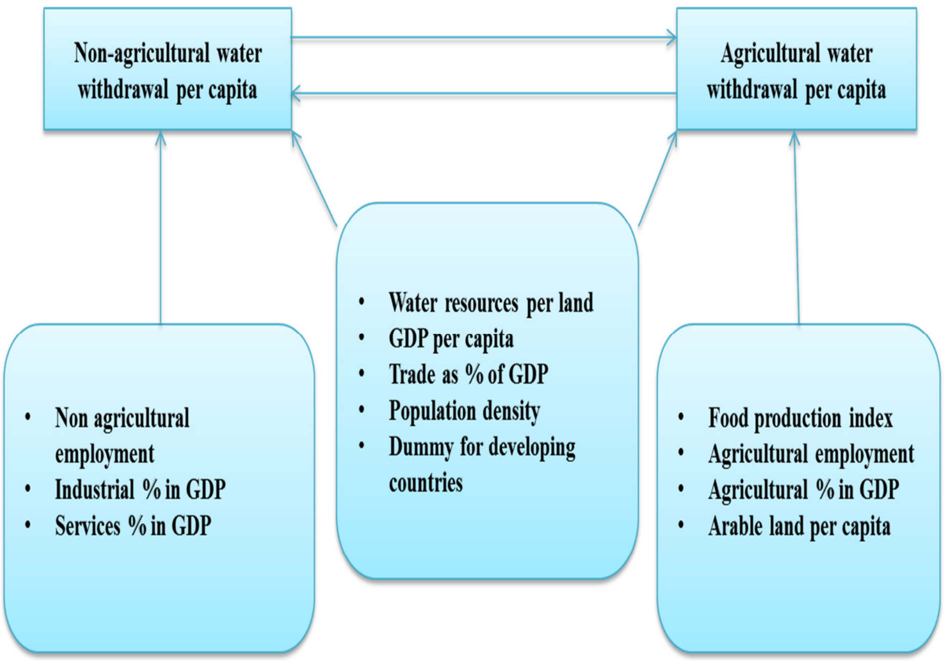

Figure 4.1: Water withdrawal and interconnection between sectors

We conduct a pooled cross sectional times series analysis, the data is summarized in table 4.1. The data on water withdrawal and annual water resources is collected from the AQUASTAT database and Gleick database of 2006 update (World Water). However, missing data of the sectorial water withdrawal reduces the number of countries to 174. We used the data of both AQUASTAT and Gleick's on an annual basis. The data on water withdrawal, renewable water resources and withdrawals for different sectors for Bosnia and Herzegovina were taken from Earth Trends (2003).

We interpolated using STATA software the missing data, the agricultural water withdrawal per capita and the non-agricultural water withdrawal per capita, in addition to the missing data of the renewable water resources. The program to do the interpolation is shown in an appendix of chapter 2. The water withdrawal is represented in our analysis as agriculture water withdrawal per capita as m^3/inhab*[25]/yr (cubic meter per inhabitants per year). The domestic and the industrial water withdrawal is represented as non-agricultural water withdrawal per capita as m^3/inhab/yr. Both the dependents variables in our model are interpolated.

The reason for interpolations here, as we have mentioned there are limited observations. This makes obtaining estimators very difficult, and may give results that may not reflect proper estimations of the model. The two solutions we left with were either interpolating the missing data or postpone the study until the proper data is available. In reality, the difference with normal practice is not that great as many variables are estimated values of the true value, including e.g. GDP. In our case the error term will comprise two elements, the true error term and the one associated with measurement error. This makes the estimates less precise than if we only had actual data, but causes no specific problem. In particular the problems associated with measurement errors for independent, explanatory variables do not arise as these are dependent variables. They do appear as explanatory variables within a simultaneous system. But within this simultaneous context they are instrumented, thus resolving the problem.

Others too have used the interpolated dependent variable including Gerring and Thaker (2008), Davies and Quinlivan (2006) and Griliches (1986). For example, Davies and Quinlivan used interpolation to fill the missing values for the human development index, assuming a straight line annual progression from one measurement to the next.

[25] inhab it is used by the AQUASTAT database, is an abbreviation for inhabitant and it is used as a description for per capita.

The actual annual water resources are the total renewable per capita from the AQUASTAT database and it is obtained by dividing the total actual renewable water resources by the total population. The water per land unit is obtained by dividing the renewable water resources by the land area which is collected from the World Bank database. The land area is measured as square km. Population density (people per sq. km of land area), and trade (% of GDP) also are collected from the World Bank database.

The income per capita impacts on the consumption of water, directly and indirectly, as an economic good relating to consumption. It is represented as value in constant 2000 USD. The value added from different sectors to the GDP is included as agricultural production as a % of GDP, similarly for the industry and services sectors. The employment is included as a % of total employment. We used the agricultural employment as an input in the agricultural sector and the non-agricultural employment, which is the sum of both the industrial and the service sectors as the % of total employment to represent the employment percentage in other sectors. All the variables are logged and summarized in table (4.1). The 174 countries included in the study are listed in the table 4.I.1 in the appendix 4.I.

Table 4.1: Summary of data

Variable in model	The source of data
Agricultural water withdrawal per capita m^3/inhab/yr	m^3/inhab/yr- AQUASTAT database 2011
Non-agricultural water withdrawal m^3/inhab/yr	m^3/inhab/yr - The sum of domestic and industrial water withdrawal per capita- AQUASTAT database 2011
Agricultural employment	As a % of total employment , World Bank Development Indicators data base
Non-Agricultural employment	% of total employment- World Bank Development Indicators data base
Arable land per capita	Arable land (hectares per person), World Bank Development Indicators data base
Agriculture % in GDP	World Bank Development Indicators data base
Industrial % in GDP	World Bank Development Indicators data base
Services % in GDP	World Bank Development Indicators data base
Food production index	Food production index shows the level of aggregate volume of food production. Food production index covers food crops that are considered edible and that contain nutrients. Coffee and tea are excluded because, although edible, they have no nutritive value- (World Bank Development Indicators data base)
GDP per capita	(constant 2000$) –World Bank Development Indicators data base
Population density	People per sq. km of land area – World Bank Development Indicators data base
Trade as percentage of GDP	World Bank Development Indicators data base
Water resource per land	Actual annual water resources per capita (m^3/inhab/yr) obtained by AQUASTAT divided by Land area (sq.km) from World Bank Development Indicators data base

Table 4.2: Influence of productivity in different economic sectors on the water withdrawal per capita (1970-2009)

	Agricultural water withdrawal per capita			
	Column(1)	Column(2)	Column(3)	Column(4)
Variable	2sls	2sls/fixed	2sls/random	3sls
Constant	315.39	347.493	272.511	357.99
	(1.29)	(1.42)	(1.2)	(1.48)
Non agr.WW/PC	0.959***	0.918***	0.971***	0.840***
	(5.34)	(5.48)	(5.44)	(4.86)
Agr. employment	0.186***	0.180***	0.186***	0.184***
	(3.99)	(3.86)	(3.99)	(4.89)
Arable land PC	-0.115***	-0.111***	-0.113***	-0.182***
	(3.34)	(3.39)	(3.3)	(6.31)
Food prod.index	-0.294	-0.398*	-0.296	-0.297
	(1.77)	(2.18)	(1.78)	(1.8)
Pop. density	-0.045	-0.036	-0.045	-0.101***
	(1.38)	(1.14)	(1.37)	(3.33)
Trade%gdp	-0.868***	-0.906***	-0.868***	-0.795***
	(10.8)	(11.18)	(10.79)	(10.61)
GDP Per Capita	-0.238***	-0.205**	-0.242***	-0.315***
	(3.39)	(2.78)	(3.46)	(4.7)
Agr.% in GDP	0.550***	0.600***	0.549***	0.361***
	(6.99)	(7.24)	(6.97)	(5.71)

	Non Agricultural water withdrawal per capita						
	Column(5)	Column(6)	Column(7)	Column(8)	Column(9)	Column(10)	Column(11)
Variable	2sls	2sls/fixed	2sls/random	3sls	2sls	2sls/fixed	2sls/random
Constant	166.12	189.479	93.381	159.279	185.124	184.407	93.316
	(1.32)	(1.51)	(0.99)	(1.27)	(1.48)	(1.47)	(1.02)
Agr.WW/PC	0.293***	0.278***	0.296***	0.329***	0.285***	0.283***	0.288***
	(7.01)	(6.74)	(7.08)	(8.21)	(6.85)	(6.93)	(6.94)
Trade%gdp	0.203**	0.155*	0.208***	0.246***	0.216***	0.158*	0.222***
	(3.24)	(2.42)	(3.33)	(4.04)	(3.46)	(2.47)	(3.57)
Water/Land	-60.188	-67.564	-34.808	-57.475	-66.469	-65.902	-34.426
	(1.37)	(1.55)	(1.06)	(1.31)	(1.52)	(1.51)	(1.08)
Industrial % in GDP	0.598***	0.592***	0.601***	0.298***	0.605***	0.592***	0.607***
	(5.64)	(5.62)	(5.65)	(3.61)	(5.71)	(5.61)	(5.72)
Services % in GDP	0.508**	0.289	0.511**	0.245	0.511**	0.302	0.514**
	(2.96)	(1.64)	(2.98)	(1.92)	(2.98)	(1.72)	(2.99)
Non Agr. emp.	0.526***	0.541***	0.529***	0.653***	0.544***	0.536***	0.548***
	(5.55)	(5.73)	(5.58)	(7.28)	(5.76)	(5.69)	(5.8)
Pop. density	0.010	0.017	0.009	0.013	0.016	0.016	0.0146
	(0.75)	(1.31)	(0.67)	(0.99)	(1.18)	(1.22)	(1.09)
GDP Per Capita	0.242***	0.264***	0.242***	0.266***	0.236***	0.265***	0.236***
	(8.2)	(9.05)	(8.2)	(9.39)	(8.03)	(9.07)	(8.02)

Agricultural water withdrawal per capita					Non Agricultural water withdrawal per capita							
	Column(1)	Column(2)	Column(3)	Column(4)		Column(5)	Column(6)	Column(7)	Column(8)	Column(9)	Column(10)	Column(11)
Variable	2sls	2sls/fixed	2sls/random	3sls	Variable	2sls	2sls/fixed	2sls/random	3sls	2sls	2sls/fixed	2sls/random
Water/Land	-109.134	-120.161	-94.151	-123.859	Food prod. index	0.244**	-0.055	0.247**	0.251**			
	(1.28)	(1.41)	(1.19)	(1.47)		(2.79)	(0.54)	(2.82)	(2.88)			
Dummy variable for developing countries	1.189***	1.154***	1.196***	1.054***	Dummy variable for developing countries	-0.992***	-0.987***	-0.997***	-1.001***	-1.016***	-0.985***	-1.023***
	(6.83)	(7.01)	(6.9)	(6.36)		(21.65)	(21.74)	(21.92)	(22.18)	(22.63)	(21.79)	(22.99)
N	1740	1740	1740	1740	N	1740	1740	1740	1740	1740	1740	1740
R^2	0.3876***			0.4002***	R^2	0.4977***			0.4744***	0.4992***		
R^2 adjusted	0.3841				R^2 adjusted	0.4948				0.49663		
F statistics	109.20***				F statistics	172.36***				191.36***		
Hausman test for 2sls fixed/ random :4.95 chi squared= 0.5503					Hausman test for 2sls fixed /random: 12.49 chi squared= 0.0856					Hausman test for 2sls fixed/ random 16.78***		
The significance of R-sq is based on F-statistics.					The significance of R-sq is based on F-statistics.					The significance of R-sq is based on F-statistics.		
t statistics in parentheses * p<0.05, ** p<0.01, *** p<0.001												

All the variables, the dependent and the independent are logged. The dummy variable in not logged.

4.5.3 Estimation results

We conduct a panel data analysis; panel data allows a combination of cross-sectional and time-series data (Song and Witt, 2000). Baltagi (2001) suggested some adventages of panel data analysis as it gives more informative data, more variability, less collinearity among the variables, more degrees of freedom and more efficiency.
We used simultaneous equation models in our analysis. The three stage least square 3SLS and the two stage least square 2SLS, where they allow for using the endogenous variables with the exogenous regressors, also they can use a linear combination of all the exogenous variables as instruments for the endogenous regressors in the model. For the fact that having the exogenous variables in one equation as an endogenous variable in another equation can lead to inconsistent estimates that can be solved by applying 2SLS and 3SLS. 3SLS was first introduced by Zellner and Theil (1962). Both 2SLS and 3SLS can deal with the endogeneity and have the capability of producing more consistent estimates than other models. Columns (1) through (11) in table (4.2) show the results estimated by 3SLS and 2SLS, fixed and random effects of 2SLS. The correlation of residual errors indicated the efficiency of the 3SLS on 2SLS, which is consistent with theory that 3SLS produces more asymptotically efficient estimates than 2SLS, for the reason that the 3SLS allows for the disturbance terms in the two structural equations being contemporarily correlated.

In column (11) for the non-agricultural water withdrawal as a dependent variable, we drop one of the instrumental variables, food production index, and rerun the regression, for the reason that its sign in the first fixed effects regression for the 2SLS in column (6) gave a different sign from the other specifications of the dependent variable non-agricultural water in columns (5) through (8), the second set of regression is present in columns (9) through (11). We notice from the table that if we go through the different specifications of the same dependent variable, the results of most of the regression did not change. We are going to elucidate the results for each one of the right hand side variables one by one:

The *population density* is significant at a 1% significant level in the 3sls model for the agricultural water withdrawal. A 1% increase in the population density leads to a 0.101 % decrease in the water use for agricultural sector. At the same time, regression analysis reflected that the population is not significant in its effect on non-agricultural water use but a 1% increase in the population density leads to a 0.013 % increase in the water use for non- the agricultural sector. However, the negative relationship between agricultural water withdrawal and population density can be due to different reasons, one of which is the influence of urbanization.

The relationships of *population density* with the agricultural water withdrawal and the non-agricultural water withdrawal per capita are illustrated in figures (4.2) and (4.3). Figure (4.2) reflects the regression results that the agricultural water withdrawal decreases as the population density increases, this is feasible on two dimensions, firstly countries with lower population density tend to use more water for non-agricultural sectors. In figure (4.3) we can see the increase in non-agricultural water withdrawal as population density increases even though this is not significant in the regressions. Both figures, but particularly the latter, suggests that this is predominantly a within countries effect, rather than a between countries one. Given the diversity of factors which can impact on water withdrawal, of which population density is just one, this is not surprising. Some examples are listed in the table (4.3) that shows some statistics for easier comparison between the variables of interest for some chosen countries. From the numbers in the table, we notice a decrease in agricultural water withdrawal per capita accompanied with an increase in population density. The increase in urbanization in some of the high population countries such as China is accompanied with a decrease in agricultural water withdrawal per capita in addition to a decrease in agricultural share in GDP. For example the water withdrawal for agriculture in 1985 is 394.9 m^3/inhab/yr accompanied by 112.68 population density per sq. km of land area and 23% of urban population. In 1990 the agricultural water withdrawal is 365.5 m^3/inhab/yr and the population density increase to 121.71 in the same year where urban population stands for 27.4% of total population. As commented before, this may reflect pressures on farmers to farm more efficiently.

An increase in the urban population (that can also be related to population density) may increase the demand for water for non-agricultural purposes, putting pressure on agricultural water. In addition, this feature can be explained by an increase in urban population and a decrease in renewable water resources. Taking China as an example (see table 4.3), we notice that as urban population increases, the renewable water resources is decreased from 2808 m^3/inhab/yr in 1982, to 2595 m^3/inhab/yr in 1987 and 2410 m^3/inhab/yr in 1992.

The regression results of *water resources per land* reflect the constraint on the supply side, which has a negative relationship with agricultural water withdrawal and the non-agricultural water withdrawal. However, this variable fails to be significant at the 10% level and hence we will not discuss it further.

Table 4.3: Sample of countries with statistics for some variables of interest

Country	Agricultural Water Withdrawal per capita	Population density (People per sq. km of land area)	Urban population (% 0f total)	Agricultural input in GDP	Renewable water resources
China	1985 1990 1993 394.99 365.5 349.2	1985 1990 112.683 121.71	1985 1990 23 27.4	1985 1990 28.443 27.12	1982 1987 1992 2802 2595 2410
Cote d'Ivoire	1994 2000 55.2 23.51	1994 2000 45.603 54.34	1995 2000 41.4 43.5	1995 2000 25.26 24.22	1992 1997 2002 5992 5093 4489
Indonesia	1990 2000 325.99 304.556	1990 2000 97.9 113.3162	1990 2000 30.6 42	1990 2000 19.4104 15.61	1993 1996 11026 10248
Japan	1980 1992 2000 496.488 472.11 427.8	1980 1992 2000 318.8 340.73 348.1	1980 1995 2000 59.6 64.6 65.2	1980 1990 2000 3.6343 2.468 1.771	1993 1998 3196 3196
Mozambique	1990 2000 39.81 30.1	1990 2000 17.2 23.21	1990 2000 21.1 30.7	1990 2000 37.12 24.1	1993 1998 7005 5939

(Source: World Bank 2011, and AQUASTATR 2011)
The dates are represented as years and underlined; the non-underlined numbers are the data.

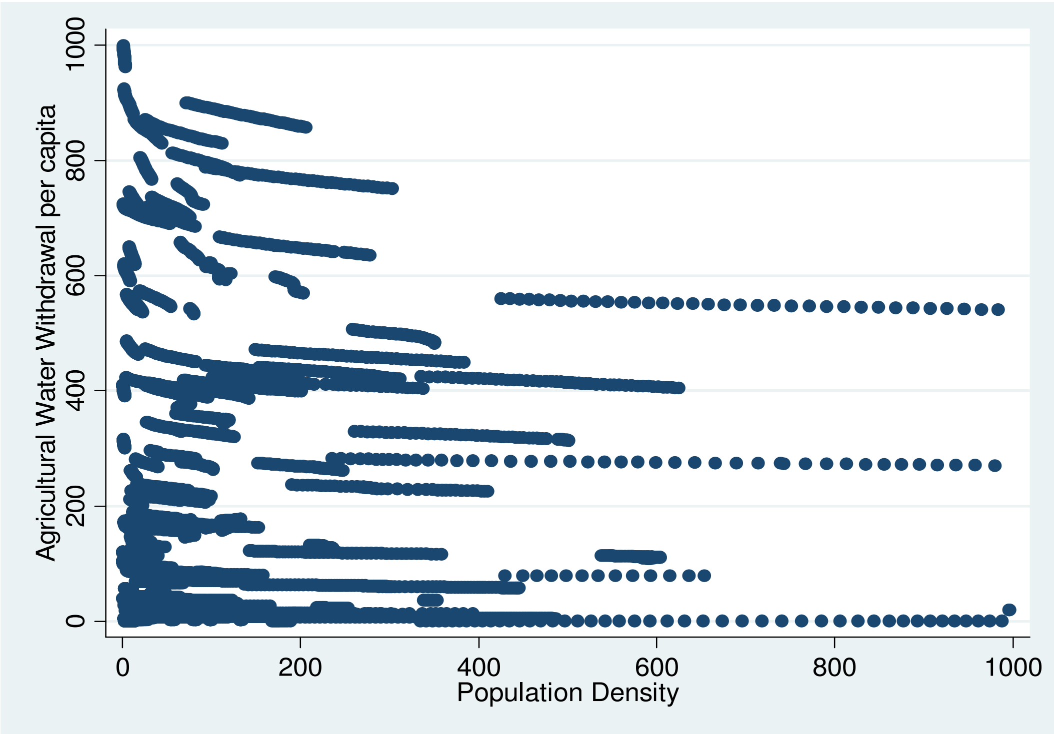

Figure 4.2: Scatter of population density with the agricultural water withdrawal per capita

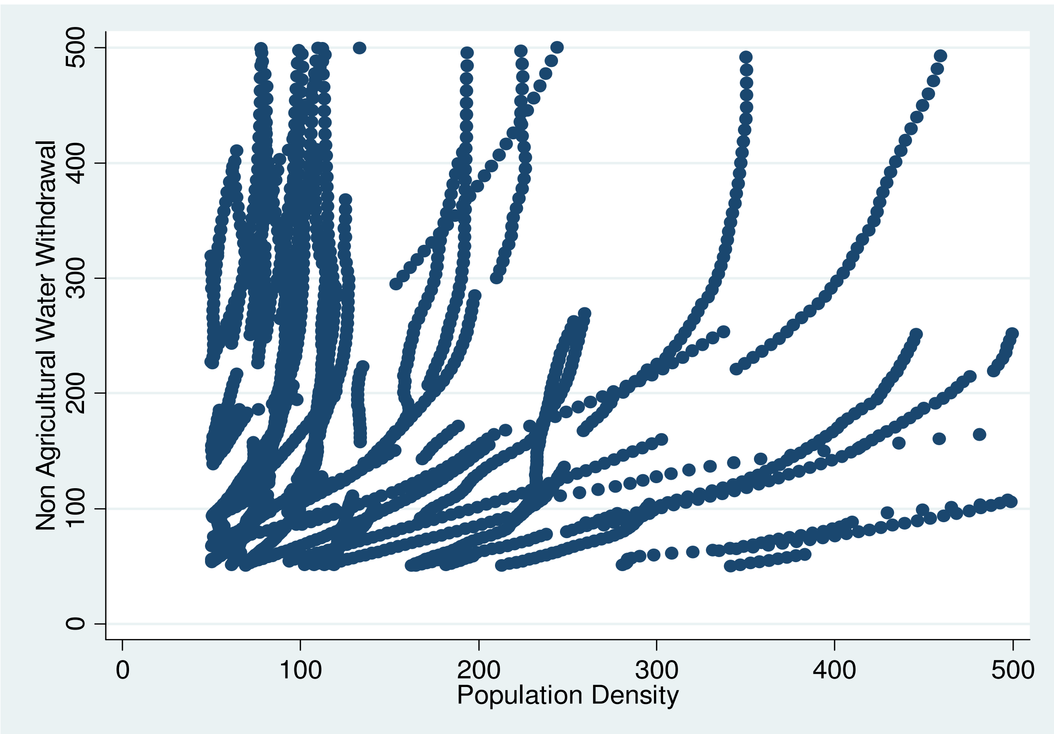

Figure 4.3: Scatter of population density with non-agricultural water withdrawal per capita

We can see that *arable land per capita* is highly significant at the 1% significance level for the agricultural water withdrawal, but the relationship is negative. Thus a 1% increase in arable land leads to a decrease of agricultural water withdrawal by 0.2%. Arable land is an input into agricultural production. If scarce it will command a high price and as our theoretical analysis suggested, producers (farmers) may respond by substituting other inputs for land, i.e. they will use more water (as an input in agriculture) to compensate for the scarcity of land. The statistics in tables 4.4 and 4.5 give an explanation; we notice that, the area of irrigated land increased between years 1980-2002, the % of arable land with respect to the total land area is not increasing or is arguably actually declining. On the other hand, land water irrigation is increasing substantially. At the same time from the last paragraphs, we have the constraint of amount of water resource allocated per land and the constraint of the density of water resource per land. All these effects sum up their influence on the decrease of agricultural water withdrawal for arable land.

We rerun the regression analysis of the 3SLS by replacing the arable land per capita with other variables[26] for different inputs in agriculture for further exploration. These variables are agricultural land (% of land area), agricultural machinery (tractors), cereal production (metric tons), cereal yield (kg per hectare), a crop production index (2004-2006 = 100), land under cereal production (hectares) and a livestock production index (2004-2006 = 100). They all failed to be significant. We rerun the 3SLS model with the agricultural land (sq. km) variable, the results are included in Table 4.6, and the agricultural land is significant at the 1% significance level, where a 1% increase in one km^2 of agricultural land leads to a 0.1% increase in agricultural water withdrawal. That complements our discussion. Arable land is not increasing it is slightly decreasing, while the percentage of the irrigated land is increasing. This emphasises the need for sufficient management for water withdrawal for irrigation.

[26] All the variables are collected from the World Bank Development indicators database.

Table 4.4: Area of irrigated land and irrigated land as a per cent of arable land

	Area of Irrigated Land (Thousand hectares)		
	1980	1990	2002
World	210,222	244,988	276,719
Developed countries	58926	66286	68060
Industrialized countries	37355	39935	43669
Transition economies	21571	26351	24391
Developing countries	151,296	178,702	208,659
Continents			
Africa	9491	11235	13400
Asia	132,377	155,009	193,869
Caribbean	1074	1269	1308
Latin America	12737	15525	17314
North America	21178	21618	23285
Oceania	1686	2118	2844
Europe	14479	17414	25220
Source: FAO, 2009	(hint: 1 km^2 = 100 ha)		

Table 4.5: Arable land as a percentage of total land area

	Arable land(% of land area)				
	2004	2005	2006	2007	2008
World	10.78491	10.75927	10.75778	10.66879	10.69205
East Asia and pacific	10.22592	10.02693	9.948484	9.471114	9.45188
European Union	26.38264	26.10825	26.06311	25.83185	25.81744
Middle East & North Africa	5.003174	4.99177	4.958679	4.979651	4.997331

Source: World bank Development indicators 2012

Table 4.6: 3SLS model for Agricultural and the Non Agricultural water withdrawal per capita after replacing the arable land per capita by the Agricultural land (sq. km).

Agricultural water withdrawal per capita		Non Agricultural water withdrawal per capita	
	Column (1)		Column(2)
Variable	3SLS	Variable	3SLS
Constant	58.86	Constant	180.1
	(0.25)		(1.46)
Non agr.WW/PC	0.908***	Agr.WW/PC	0.272***
	(5.41)		(5.73)
Agr. employment	0.228***	Trade%gdp	0.180**
	(5.61)		(2.60)
Agricultural land (sq. km)	0.0996***	Water/Land	-64.43
	(4.68)		(1.50)
Food prod.index	-0.339*	Industrial % in GDP	0.355***
	(2.06)		(4.17)
Pop. density	0.0613*	Services % in GDP	0.154
	(2.27)		(1.14)
Trade%gdp	-0.908***	Non Agr. emp.	0.647***
	(12.25)		(7.30)
GDP Per Capita	-0.328***	Pop. density	0.0146
	(5.05)		(1.11)
Agr.% in GDP	0.277***	GDP Per Capita	0.255***
	(4.38)		(8.76)
Water/Land	-18.72	Food prod. index	0.239**
	(0.23)		(2.78)
Dummy variable for developing countries	1.258***	Dummy variable for developing countries	-0.969***
	(8.51)		(21.19)
N	1749	N	1749
R^2	0.3908	R^2	0.5045

t statistics in parentheses * p<0.05, ** p<0.01, *** p<0.001
All the variables, the dependent and the independent are logged. The dummy variable in not logged.

The *food production index* has a negative impact on the agricultural water use which is surprising but it is not significant, a 1% increase in food production is accompanied by 0.3% decrease in agricultural water withdrawal, this relation is consistent and observed with the fixed and random effect of the 2sls model. The situation is different with non-agricultural water where it is significant at 1% significant level, and a 1% increase in food production leads to a 0.25% increase in non-agricultural water withdrawal. This can be explained by different effect channels. An increase in food production leads to an increase in food manufacturing and processing, like canning food transforming and trading,….etc. Another explanation can be due to the decline in the renewable water resources in some part of the continents (the time effect and the climate change influence) especially where a food production depends on the irrigated lands (see figures 4.4, 4.5, and 4.6). But the essence is that, a higher food production leads to higher demand for agriculture water and puts pressure on non-agricultural uses. In this sense the two are competitive. Production of food needs water, land and labour as inputs on production (both included in the regression). For example, Brown and Halweil (1998) illustrated the fact that the water shortages in northern China would force China to import up to 210-370 million tons of crops annually to feed the huge population in 2025, and use water for other sectors. For more illustration, we report the result of the regression of the non-agricultural water withdrawal after omitting the food production index variable (columns 9 through 11 in table 4.2), and we noticed that they did not change[27].

[27] We rerun the 3SLS and the 2SLS models after dropping the food production index from the models in column (1)-column (8), we noticed that our results did not change.

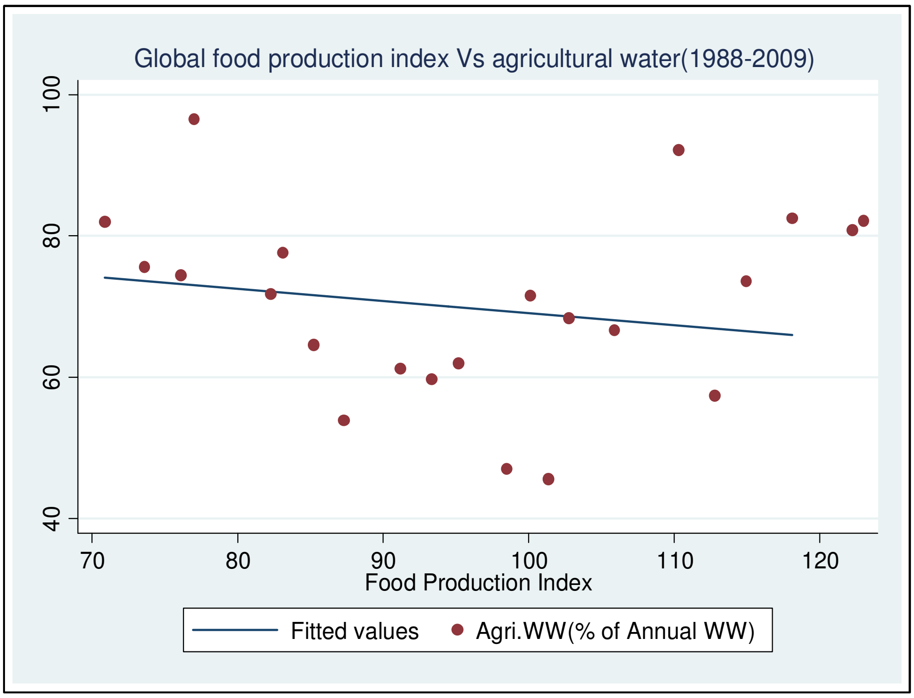

Figure 4.4: Scatter plot of Agricultural water withdrawal and food production index

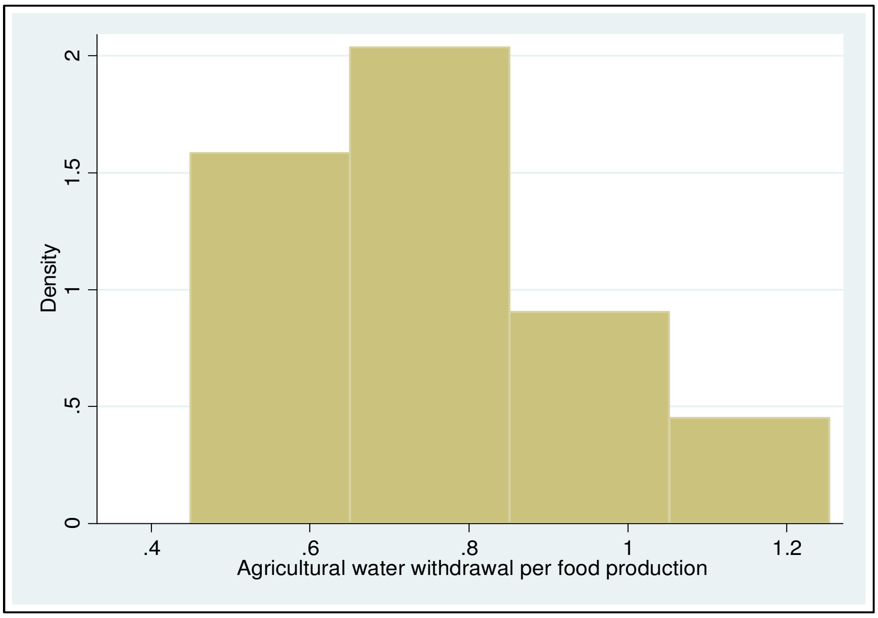

Figure 4.5: Histogram of Agricultural water withdrawal per food production

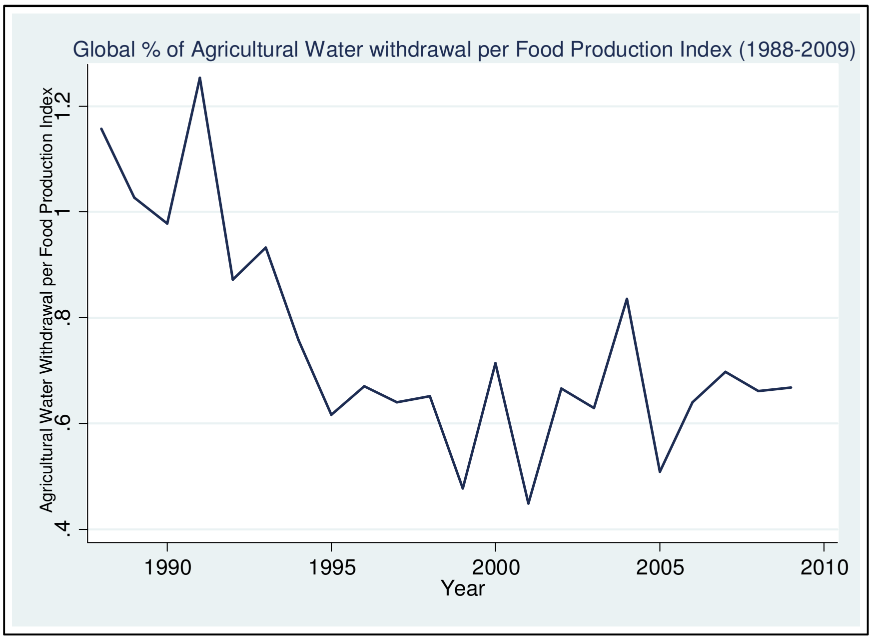

Figure 4.6: Times series trend in global % of agricultural water withdrawal per food production index

As for *trade as a percentage of GDP*, it has a negative and significant effect on the agricultural water withdrawal, and this result is consistent going through the regression results of the 2sls and the 3sls models. Trade is also significant for both the agricultural and the non-agricultural water withdrawal at the 1% significance level, an increase by 1% in trade decrease the agricultural water withdrawal by 0.8 %, and an increase of trade by 1% increases the non-agricultural water withdrawal by 0.24%. Trade as % of GDP and the increase in the non-agricultural water withdrawal is illustrated in the scatter plot in figure (4.7) which reflects an increase in non-agricultural water withdrawal as trade % of GDP increases. As with population density this may reflect competitiveness effects. Trade opens up the way to prosperity and that can increase the demand for non-agricultural usage. In entering global markets, farmers have to compete with foreign producers and that may force the use of more efficient techniques which again may force the more efficient use of water. In addition trade is associated with knowledge transfer and new knowledge and ways of doing things, may lead to both increases in non-agricultural and declines in agricultural water usage.

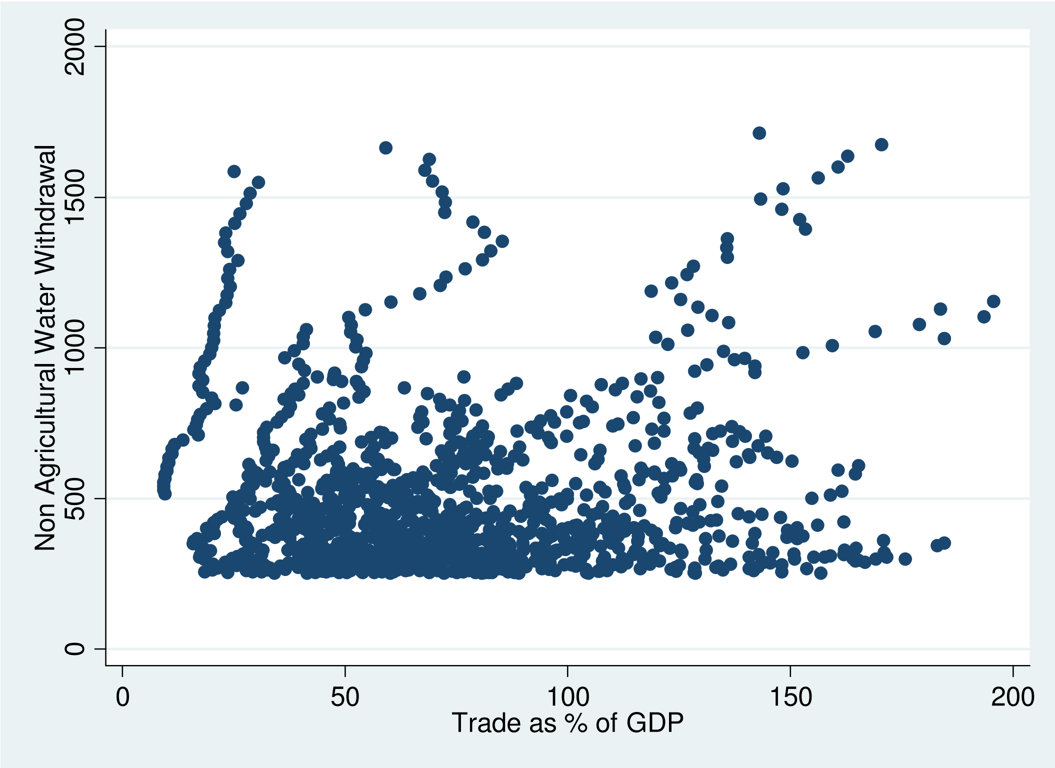

Figure 4.7: Scatter of non-agricultural water withdrawal per capita with Trade as % of GDP

The *GDP per capita* is negative at the 1% significance level on the agricultural water withdrawal and positive at the 1% level in its effect on the non-agricultural water withdrawal, at the same time the *agricultural percentage of GDP* is found to be significant at the 1% level in its effect on the agricultural water withdrawal, a 1% increase in agricultural input in GDP is accompanied by 0.4% increase in the agricultural water withdrawal in the 3sls model, while it is accompanied by 0.5% increase in the water withdrawal for agriculture according to the random effects model of the 2sls (Hausman test directing the choice for the random effect as the appropriate model). The negative relationship between the *GDP per capita* and the agricultural water can be explained by the fact that must of national agricultural output could be consumed internally giving less effect compared to the non-agricultural sectors' input in the GDP. Also, it can be a negative relationship due to the income effect, as consumers get richer; their life style becomes more water intensive, which increases the demands for water for different economic sectors on the account of the agricultural water withdrawal. Finally increase in GDP per capita may correlate with a more technically advanced country with the expertise to be able to use water more carefully. There is the possibility that the agricultural sector is endogenous, but the general result that increased agricultural focus increases water for agriculture is likely to be valid.

As for the non-agricultural water withdrawal, the *GDP per capita*, the *industrial and service percentage of GDP* are exerting a positive significant effect on the water withdrawal for non-agricultural sectors. This means that the economic prosperity is highly associated with the non-agricultural water withdrawal. It implies that if living standards in a country are doubled, the demand for non-agricultural water will increase by about 0.5%. GDP is negatively associated with the agricultural water withdrawal, which suggests that there is higher national demand for crops and agricultural outputs is higher than supply, adding the effect of other factors like climate change and natural disasters that hampers the output harvesting in different regions in the globe. However, economic changes and advancement play an important effect by shifting the economic growth towards industry and services due to openness and globalization. Additionally, this can be due to the price mechanism at work. Increasing demand for non-agricultural water as GDP per capita increases drives up the opportunity cost of water if not the price of water, forcing farmers to reduce their use of it. Other influences can be that the increase in GDP can enhance technological advancements that can improve water managements and efficiency in using water. For more clarity and illustration about the relationship between GDP per capita and the water withdrawal for agricultural and the non-agricultural sectors we introduced the scatters with different relationships, (see figures 4.8 and 4.9).

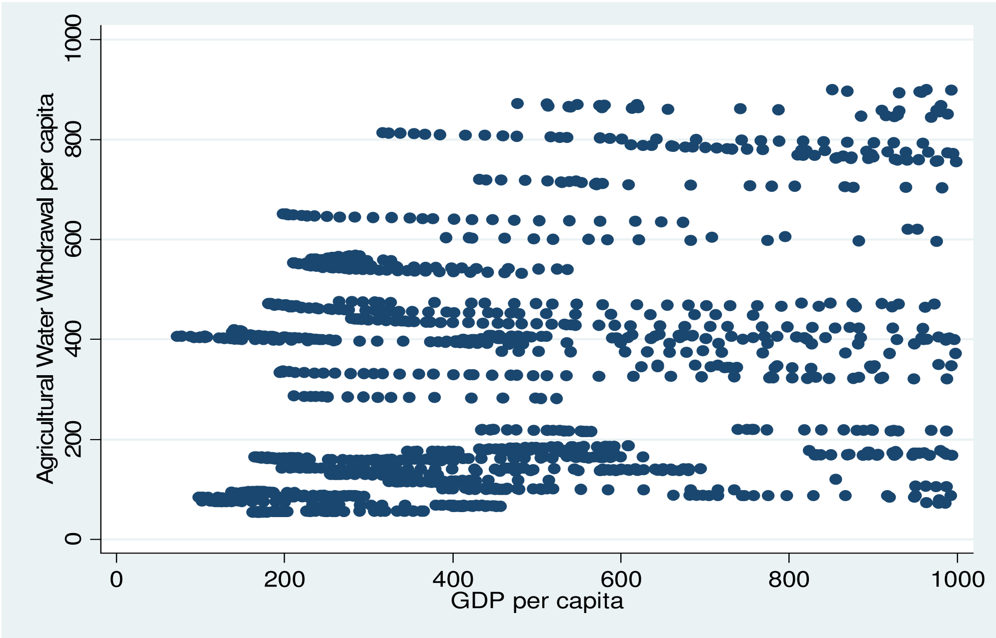

Figure 4.8: Agricultural water withdrawal and GDP per capita

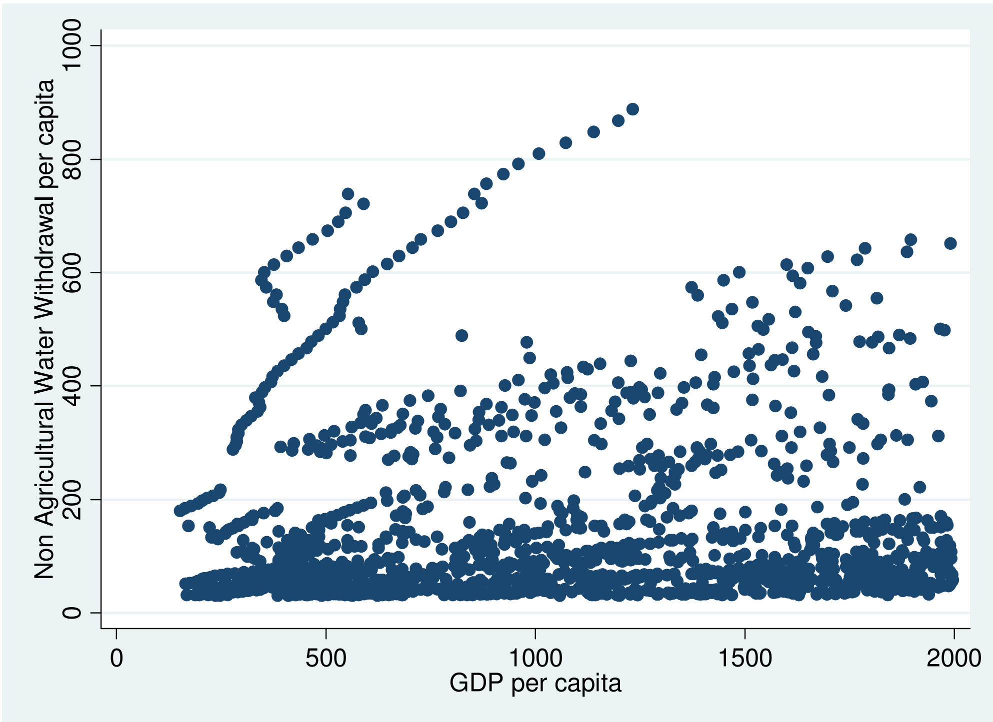

Figure 4.9: Non Agricultural water withdrawal and GDP per capita

Agricultural labour is significant at a 1% significance level, a 1% increase in the agricultural employment leads to a 0.2% increase for water withdrawal for the agricultural sector. Clearly, the *non-agricultural employment* has a 1% significance level impact on the non-agricultural water withdrawal. A 1% increase in non-agricultural employment tends to increase the non-agricultural water withdrawal by 0.6% in the 3sls model and by 0.5% according to the 2sls model. These factors also reflect the importance of industry structure on water demand.

The *dummy variable* is significant at the 1% significance level, which is consistent with the idea that most of the developing countries are agricultural societies. Concerning the dummy variables, aside from all the variables in our model, they are not logged in the regression, which requires a calculation to explain their impact on the agricultural and the non-agricultural water withdrawal per capita. First, we used a dummy equal to 1 for developing countries and equal to zero for the developed countries. In the equations of the regressions for more clarity we have:

Log (Agricultural water withdrawal per capita)= β_0 + log (variables) + dummy variable

Log (Non-agricultural water withdrawal per capita)= β_0 + log (variables) + dummy variable

This can be calculated as:

Agricultural water withdrawal= (take the list of variables here as 100) x $e^{+1.05\ \text{Dummy}}$

Non-agricultural water withdrawal= (take the list of variables here as 100) x $e^{-1.001\ \text{Dummy}}$

If Dummy =1, then the Agricultural water withdrawal for developing countries increase over the developed countries by an approximately 30 %, and the non-agricultural water withdrawal for developing countries in less than that of developed countries by 35%.

Our finding that *the agricultural and the non-agricultural water withdrawal* are positively significant at the 1% level in the two equations , shows that water withdrawal for different sectors is to an extent uncompetitive. This finding is in agreement with Longo and York (2009), who suggest that the water development in the agricultural sector has a spill over effect on water development for other sectors in the economy. In our results it is significant at the 1% level. This supports York and Longo suggestions that there is a synergistic relationship between water development and water withdrawal for agriculture and non-agricultural withdrawal. In our analysis, this synergy goes in both directions. However this conclusion needs qualifying by the significance, with opposite signs of different variables in the two equations. This is most notably the case with trade and GDP per capita. The results suggest, e.g., that increasing prosperity increases the non-agricultural demand for water for diverse reasons and this results in a decline in water for agricultural purposes.

4.6 Conclusion

The results of the regression showed the influence of trade openness and economic growth on water withdrawal for different sectors of the economy. This indicates that developments and advancements in infrastructure that support water provision for different sectors within a water management context interact with each other. Also this is consistent with the fact that improved water provision increases economic productivity for different economic sectors at the national level. In addition, the negative impact of water resources per land on both kinds of water withdrawal is a clear reflection that water constraints are impacting on water withdrawal. This may well be further affected by population density, urbanization and trade liberalization as is evident in the negative impact of trade on water for agriculture and trade as % of GDP, in addition to climate change effect. Labour proved their part as a positive significant input in agricultural, industrial and services sectors, this reflects industry structure.

As for the non-agricultural water withdrawal, there is a clear link with GDP per capita. As societies get richer so their pattern of demand for water shifts from agricultural to a non-agricultural uses. All these results proved the important role of water as both an economic and social good in economic development in different sectors of the economy. Water encompasses and interferes in all aspects of human development. In general, the increase in population density and GDP increase the demand for water. Also, the developing countries' dummy variable indicates that there is a considerable scope for developing countries to use water more efficiently.

The results indicate that as we move forward, as countries become more prosperous and as trade increases there will be an increasing demand on water for non-agricultural purposes. This will put pressure on the agricultural sector which may eventually lead to crisis and rising in food prices. But the evidence that developing countries are inefficient in their use of water holds out the hope that efficiency gains in the future can help reduce this pressure on the agricultural sector. In this case less may become more, in the sense that reduced agricultural usage of water may produce more food. Successful water management is necessary in solving the critical socioeconomic and environmental issues facing humanity. Water scarcity is often a major constraint where water stands in the middle as an input (economic good as stated in chapter 2) that satisfy the competition between different human activities, and creative water management stands as a mean to solve, tackle or most precisely to alleviate one of the toughest global challenges during the twenty first century.

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Appendix 4.I

Table 4.I.1: List of 174 countries included in the study

The List of 174 countries included in the study				
Afghanistan	Comoros	Iceland	Mongolia	Spain
Albania	Congo, D. R.	India	Morocco	Sri Lanka
Algeria	Congo, Rep.	Indonesia	Mozambique	St. Lucia
Angola	Costa Rica	Iran, Islamic R.	Myanmar	Sudan
Antigua and Barbuda	Cote d'Ivoire	Iraq	Namibia	Suriname
Argentina	Croatia	Ireland	Nepal	Swaziland
Armenia	Cuba	Israel	Netherlands	Sweden
Australia	Cyprus	Italy	New Zealand	Switzerland
Austria	Czech Republic	Jamaica	Nicaragua	Syrian Arab Republic
Azerbaijan	Denmark	Japan	Niger	Tajikistan
Bahrain	Djibouti	Jordan	Nigeria	Tanzania
Bangladesh	Dominica	Kazakhstan	Norway	Thailand
Barbados	Dominican R.	Kenya	Oman	Timor-Leste
Belarus	Ecuador	Korea, D.R.	Pakistan	Togo
Belgium	Egypt, Arab Rep.	Korea, Rep.	Panama	Trinidad and Tobago
Belize	El Salvador	Kuwait	Papua New Guinea	Tunisia
Benin	Equatorial Guinea	Kyrgyz Republic	Paraguay	Turkey
Bhutan	Eritrea	Lao PDR	Peru	Turkmenistan
Bolivia	Estonia	Latvia	Philippines	Uganda
Bosnia and	Ethiopia	Lebanon	Poland	Ukraine
Herzegovina	Fiji	Lesotho	Portugal	United Arab Emirates
Botswana	Finland	Liberia	Puerto Rico	United Kingdom
Brazil	France	Libya	Qatar	United States
Brunei D.	Gabon	Lithuania	Romania	Uruguay
Bulgaria	Gambia	Luxembourg	Russian Federation	Uzbekistan
Burkina Faso	Georgia	Macedonia, FYR	Rwanda	Venezuela
Burundi	Germany	Madagascar	Saudi Arabia	Vietnam
Cambodia	Ghana	Malawi	Senegal	West Bank and Gaza
Cameroon	Greece	Malaysia	Serbia	Yemen, Rep.
Canada	Guatemala	Maldives	Seychelles	Zambia
Cape Verde	Guinea	Mali	Sierra Leone	Zimbabwe
Central African R.	Guinea-Bissau	Malta	Singapore	
Chad	Guyana	Mauritania	Slovak Republic	
Chile	Haiti	Mauritius	Slovenia	
China	Honduras	Mexico	Somalia	
Colombia	Hungary	Moldova	South Africa	

Chapter 5

Safe Access to Water and sanitation

5.1 Introduction

Pressure for a sustainable development has grown by the World Bank and other international institutions with the concern of entitling water as a part of the economic development. The United Nations declared the twenty second of March 2005 as the world's water day, they announced the start of the action Water for Life as a mean for achieving the Millennium development goal (MDGs) for the easy access to a safe water and good sanitation, the action decade will spread from 2005 until 2015, by 2015 people who are subjected for access to unsafe water and improper sanitation would be reduced to the half. These goals were reported and agreed on in the World Summit on Sustainable Development in the Johannesburg (2002) plan to implement this millennium goal.

Likewise, the Human Development report (2006) considered the Access to safe water as a basic human need and an ultimate contribution for human rights. The annual economic benefit from reaching the MDGs is accounted for 84 billion US dollar. According to WHO (2002), poor access to safe water and basic sanitation, lead to poor health situations accompanied by a high mortality rate in addition to other serious health issues. In general, productivity within the microeconomy depends on the productivity of different economic sectors within the economy, the production capacity within the economic sectors depend on the factors of production, in which the health of labour and people play a vital role in productivity. Benefits from investment in improving water and sanitation outweighs the costs of operations. Access to clean water and basic sanitation helps to improve health and thus the labour productivity. For example, the Stockholm International Water Institute (SIWI, 2005) mentioned that the benefits of investing in water and sanitation exceed costs and that observations proved a 3.7% growth in GDP in poor countries after improving their water and sanitation. Table 5.1 contains some facts about the benefits of improving water and sanitation.

Our aim in this study is to highlight the various factors that affect and contribute in reaching the MDG goal target 7. Concentrating on the important factors which affect the international efforts in reaching this goal, addressing more the effect of water and sanitation- target aid and its volatility. In other words focusing on water and sanitation sector-allocable aid. Most previous literature focused on the volatility of aid as a total effect on total public sectors. The study aims to fill the gap in the literature to explain what undermines the different factors that affects the development of water and sanitation subsectors. The importance of this exploration is to get an idea about the possibility of reaching the MDG goals[28]. Water and sanitation are important for the productivity, the advancement of the national growth, and in the socio economic sustainable development, also it is pivotal in reducing poverty and in the improvement of different economic sector. We will focus on the impact of internal factors and the external support as well on the improvement of the water and sanitation sector, and their effect on growth within the country.

Previous studies deal with the volatility of aid use taking the aggregate aid into consideration. Some studies explored the volatility of components of aid (Bulír and Hamann. 2003). Our research is motivated by two puzzles, the first one is to explore the amount of aid and its volatility for water and sanitation and shed the light on this fact. Despite the importance of this sector still little global attention is given to its importance and connectivity with different socio economic factors and on the health sector. The second puzzle is the minor funds that are allocated for this sector. From (SIWI, 2005) report, five messages are issued to develop the modus operandi of the policymakers to deal with water as a part of the economic development. The first message links the improvement of water resources with growth by taking as an instance that poor countries with better access to water resources and improved sanitation exhibited annual economic growth by 3.7% whereas those of poor W&S were accredited to 0.1% of growth.

[28] The official definition of the Drinking Water and Sanitation MDG target (MDG targets 10 and 11), one of the three targets within the seventh MDG focusing on environmental sustainability, is as follows: “Halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation”. Two indicators were designed to monitor progress towards this target and are used by the Joint Monitoring Programme (“JMP”), the official mechanism within the United Nations for monitoring international goals on access to drinking-water and sanitation:

- Indicator 30: Proportion of population with sustainable access to improved water source, urban and rural;
- Indicator 31: Proportion of population with access to improved sanitation, urban and rural.

Table 5.1: Statistics illustrating the benefits from investing in water and sanitation

- The costs of the cholera epidemic that had spread across Peru in 1991 cost one billion USD to be treated, while prevention of the epidemic could have cost one tenth of this cost according to estimations (Suarez and Bradford, 1993).
- Improved W&S can decrease diarrhoea by 25% (Moll *et al*., 2007).
- In sub-Saharan Africa, women spend more than 6 hours wasting productive time to collect water, according to WHO estimates, saving that time would contribute highly to reach the MDGs by saving of 64 billion USD, Whittington (1990) estimated the cost of time spent in collecting water in Kenya to be in the same value of the average wage rate for an unskilled labour.
- Unsafe contaminated drinking water with industrial and municipal waste water affects the mental and the physical health of children in China ((China Council for International Cooperation on Environment and Development (CCICED) in (Warford and Yining, 2002, chapter 3; Hansen and Bhatia, 2004)
- Hutton *et al*. (2007) in a cost benefit analysis of improved W&S concluded that benefits exceed costs in improving in all world sub-regions and the return on a US$1 investment was between US$5 - US$46 in developing regions. While the WHO (2006) estimated that a US $1 invested in safe water supply, sanitation and hygiene (WASH) gives a payback US$8 economic benefit.

5.2 The share of aid to water supply and sanitation in total aid

To understand the structure of the ODA (official development assistance) for water and sanitation see figure 5.1 that explains the ODA in general perspective. ODA is divided into bilateral aid in which assistance is given directly to the developing countries, and multilateral aid, which is provided through international organizations. The Development Assistance Committee DAC's report (2004) defines aid to water supply and sanitation as: *including water resources policy, planning and programmes, water legislation and management, water resources development, water resources protection, water supply and use, sanitation (including solid waste management) and education and training in water supply and sanitation. The definition excludes dams and reservoirs primarily for irrigation and hydropower and activities related to river transport (classed under aid to agriculture, energy and transport respectively).* As the concern increases to reach the MDG goals, the sectoral aid (ODA) has increased by 35% between 2002 and 2004. Generally, after the decline of aid for water and sanitation during the 1990s, it is evident that the commitment for the MDG goals has had its influence; aid for W&S has increased. Aid for water supply and sanitation has risen since 2001 but with the rise is not enough compared to aid for education and health sectors that call for increasing interest in water and sanitation.

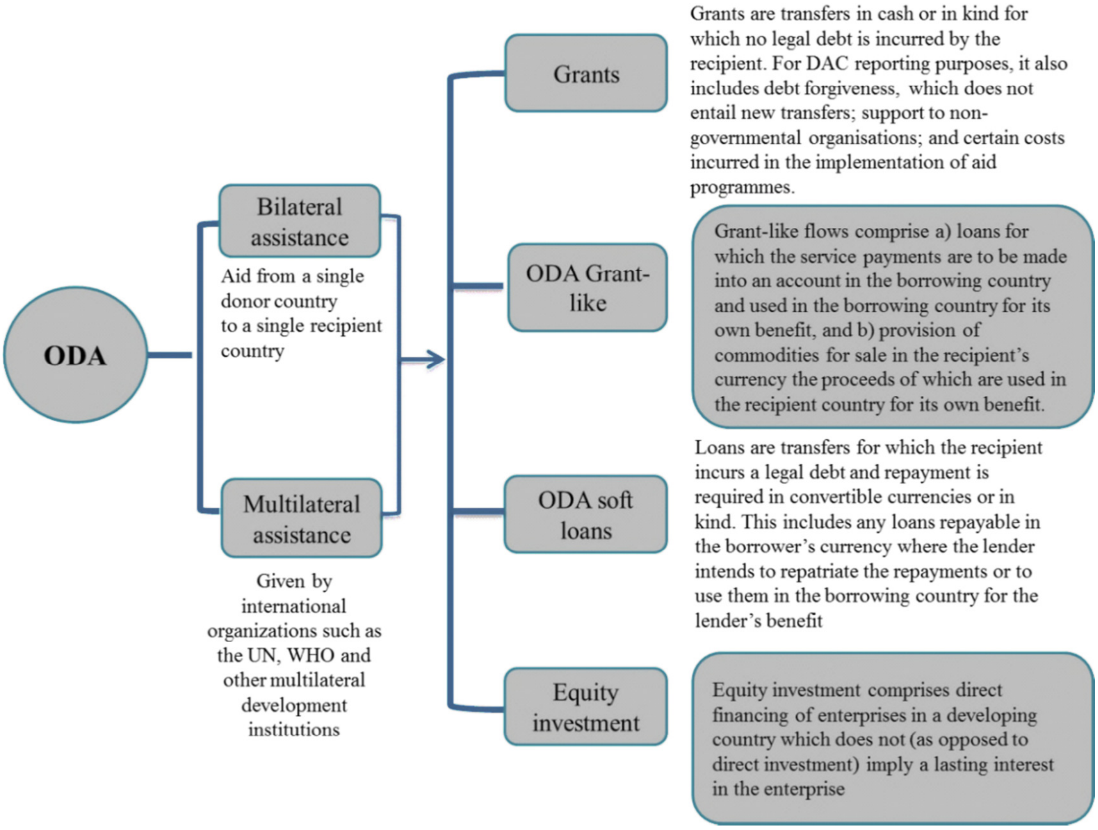

Figure 5.1: The official development assistance, all the definitions are taken from the OECD.

Global concern of the importance of the water and sanitation to alleviate poverty and realisation of their part in economic development, in addition to other impacts such as on health sector, is apparent in the percentage of water aid in the bilateral aid over the period 2001-2006 to become approximately 9% of the ODA. The increased awareness in the number of the individual donors to this sector is reflected in figure 5.2, which illustrates the moving average for global commitment for water and sanitation between the mid-1990s and 2010. We can see the increasing trend in countries´ commitments for these two subsectors.

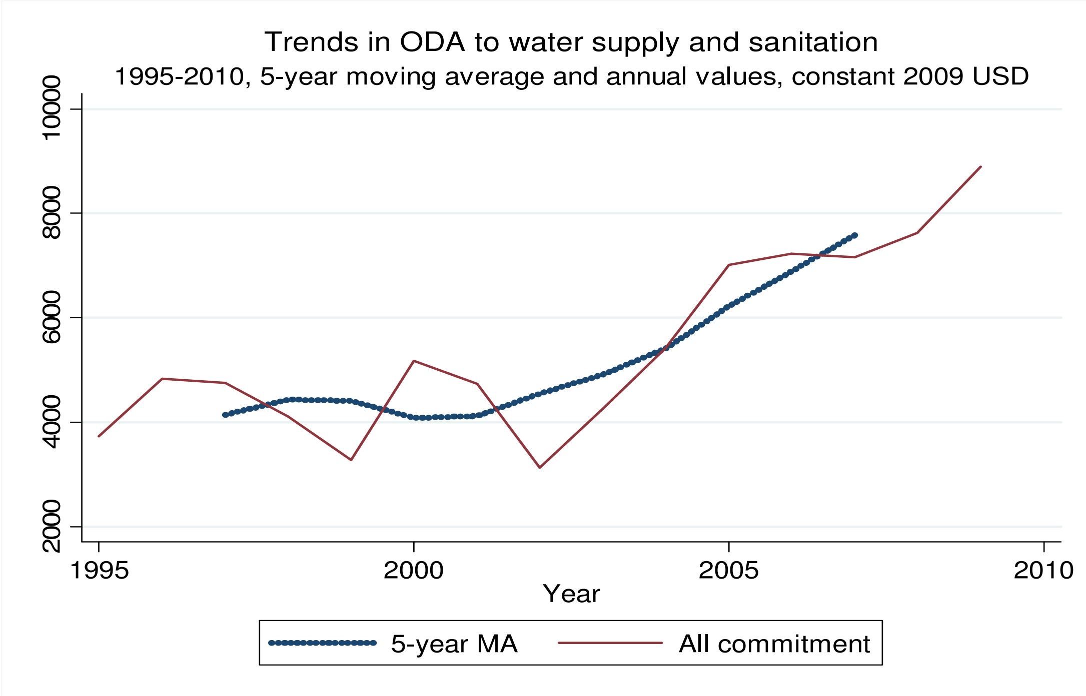

Figure 5.2: Five years moving average and yearly global aid commitment for water and sanitation

5.2.1 Financing water and sanitation

Early estimations from the issuers of the MDG goals suggested the financing needed to achieve the goals to be about 0.25 percent of the donors` GDP in 2003 and 0.44 percent in 2006 reaching to 0.54 percent in 2015, which accounts for US$120 billion each year of aid (UN, 2005). Most of this ODA is allocated for health which emphasises the importance of the effectiveness of ODA for water and sanitation due to the strong link to the health sector (see table 5.1). The cost assessment for target 10 of the MDGs varied from 9 billion (WHO, 2004) to 30 billion USD per year (GWP, 2000 and World Bank, 2003 from the World Water Council report (2006, p.7). The difference in assessment is due to different reasons, such as the restrictions in the definition of the target 10, the different means of analysis and calculations that lead to a weakness in estimating the unit cost. Another reason is the lack of and the need for consistent data for safe access to water and sanitation, along with additional costs of instalment of infrastructure that can be highly expensive in some regions of the world, in addition to maintenance, water storage costs (World Water Council, 2006; Mehta *et al*., 2005). So far, the estimates of the required finance for water and sanitation sub sectors show a fluctuation in the funding. The financing of the sector needs to be prudently regulated to improve the performance of the sector and help to increase the percentage of population with the safe access for water and sanitation, especially in Africa which is behind in meeting the MDG goals. According to Winpenny (2003) global finance for safe access to water is estimated to be US$13 billion/year and US$17 billion/year for proper sanitation. Also, different reports estimate that the sanitation target will be two to five times more than the water target. For the developing world, total investment in water and sanitation is projected to be between 14 and 16 billion USD annually (without including waste water treatment) (GWP, 2000; Winpenny, 2003; Toubkiss, 2006, p. 7).

Hutton and Bartram (2008) mentioned the lack of studies that deal with the costs of improving the infrastructure to supply water and sanitation. He commented on the fact that although the target 7 distinguished the urban and the rural areas in its definition, there is no special arrangement for the means that rural and urban areas are to be treated separately. Furthermore, this affects the unit costs because infrastructure, technologies and population growth differ between rural and urban areas, which generate a lack of credibility in the unit cost estimations (Hutton and Bartram, 2008). After declaration of the MDGs in 2000, different studies have been done estimating the costs needed to attain water and sanitation goals, either at the global level or at the regional level.

The effective financial delivery can lie in structurally adjusting the system in the donor- recipient relationship to deliver the aim without the systemic fragility that undermines the efforts from different involved parts. The effectiveness of aid in the recipient countries has been explored in the literature by different studies. Mavrotas and Ouattara (2007) found that both project aid and financial programme aid have a positive impact on the total expenditure. Specifically, project aid increases capital expenditure at the same time the financial programme is associated with an increase in government consumption.

The Department for International Development (DFID) distinguishes between results based aid (RBA) and results-based financing (RBF) according to their funding source and the contracting arrangements. Trémolet (2011) uses the RBF in distinguishing between the instruments that are used at macro level (between a donor and a government), and instruments used at a micro level (channels of financing on the supply side or on the demand side like a private operator, an NGO, or a household). Thus far sanitation has lacked the interest that health, education and water have received. According to this report, financing the water sector takes place as a COD (cash on time) which is a RBF instrument that is delivered from the donor country to the finance ministry of the recipient one. There is debate about the probability of using the COD for sanitation as well. Also, this report proposed an OBA (Output-Based Aid, ties the disbursement of public funding to the achievement of clearly specified results that directly support improved access to basic services, this subsidy fund paid directly for the committed part to deliver the service whether it is private or public), which has so far a limited usage in the sanitation sector. Few countries used this instrument, some of which are Mozambique, Brazil and India, Senegal. In Morocco, it is used for both water and sanitation. Another groups of interest proposed the AMC (advance market commitments) which is widely used for the health sector. It can be used when there is a need for development of a new product which can be applied by different procedures, in the case that the public sector acts as a purchaser for sanitation services. Software support to sanitation is an example of this instrument, where the government runs a competition between companies to deliver these services as services, and rewards them by giving a "guaranteed market to these providers".

According to Mehta *et al.* (2005), three requirements are vital to meet the MDG goals for water and sanitation. First, a proper infrastructure and a proper maintenance are required in place of the existing ones. A frequent maintenance of these infrastructures requires the keeping of reserved funds. Finally meeting the required development for these sectors needs continuous finance together with the reforms for the required policies to meet the required monitoring and cooperation for efficient performance. Okun (1988) stated that the provision of effective water supply and sanitation depends on domestic rule and on advancement and awareness education concerning the health sector. It is not enough to install an infrastructure for the provision such as pumps, wells, pipes but it is also needed for a proper intervention in the recipient countries in planning. Good responsible management of the projects is highly recommended by the international interest groups. Okun also mentioned the importance of finance for these projects and monitoring of the performance after installation. He pointed at the failure in some regions *"Africa, Asia, and Latin America are littered with inoperative pumps, wells, pipes, and treatment plants that may have been well conceived at the office of a donor agency and/or a country ministry but fell into disrepair because of the absence of local commitment at all stages of the project. Community participation, including local financing, has been the hallmark of successful sustained projects,* (Okun, 1988, p.1464)*"*.

5.2.2 The absorptive capacity of aid

This is linked to the marginal rate of return to aid. Two points needed to be highlighted here. First of all, the economic growth of the individual country within the macroeconomic context, and the second, is to deal with microeconomic constraints that play a role in the specific sectorial ODA to reach the MDG goals. Bourguignon and Sundberg (2006) argue that the rapid increase in the ODA for low income countries with limited capabilities, may cause an increase in the unit costs and the public services may be of a poor quality. Absorptive capacity plays a role in limiting the impact of foreign aid when the rate of return on further increments of aid falls to some minimum acceptable level (Radelet, 2003). Feeny and McGillivray (2011) illustrate the general impact of aid on growth is an inverted U shape curve. Feeny and De Silva (2012) used the statement introduced by Feeny and McGillivray (2011) that *"As donors continue to scale-up their assistance, it is important that the effectiveness of aid at promoting growth and reducing poverty is not compromised by over-aiding recipients relative to their levels of absorptive capacity"* to propose the possibility of introducing the absorptive capacity in modelling the effect of aid on growth. They introduce a composite index of absorptive capacity (CIAC), an index that stands for all the constraints that affect the payback of aid for both the recipients and the donors. In general it sums up the human, physical capital, social, cultural, institutional and policy constraints, in addition to the macroeconomic' constraints.

According to World Bank (2002), the flows of foreign aid may increase to create macroeconomic and structural complications, due to the quantity of aid and its allocation between the tradable and non-tradable sectors. High levels of aid can bring `Dutch disease ` which hampers growth due to a decrease in exports. In 2005, the international development community agreed on increasing the ODA, to be doubled by 2010 for low income countries. Although aid is good for growth for low income countries, additional aid to GDP can have little effect on growth due to the effect of different constraints like institutional, human capital, professional work force, macroeconomic indicators (World Bank, 2004). In the case of sectorial aid the main constraint is the physical capital due to the contribution of the infrastructure. The lack of suitable infrastructure in the recipient countries will affect the effectiveness of the allocated aid for that sector. Considering aid for water and sanitation, a lack of pipes, dams and suitable infrastructure, will lead to the allocation of high amounts of the received aid for the instalment of the required systems and will slow down a delivery of the required service.

5.3 Effect of aid volatility

5.3.1 Effect of aid volatility on growth

The economic consequences of volatile aid can be significant in high aid recipient countries, especially in poor countries that can cease the completion of established development projects which affect the rate of return. The fluctuations of inflows lead to a disturbance in expenditure that creates an uncertain environment and affects the institutions and the current policies which repels the investments (Hudson and Mosley, 2007). Much of literature deals with the effect of aid on growth, some studies find that the impact of aid on development is nearly nothing (Rajan and Subramanian, 2008a), while Easterly (2007) found a negative effect of aid on growth. Bulír and Hamann, (2003) conducted a study covering 72 countries to explore the volatility of aid flows and that of domestic revenue in aid recipients. Aid flows have volatile characteristics and in general are pro cyclical in nature (Bulir and Hamann, 2003; Gemmell and McGillivray, 1998 and Pallage and Robe, 2003). Aid has a robust effect on economic growth by the enhancement of investment (Lensink, and Morrissey, 2000) who found that aid volatility has a negative and a significant effect on growth. McGillvray and Morrissey (2000b) research aid's broader macroeconomic impacts, by examining its impact on fiscal behaviour, specifically, the impact of aid on public sector fiscal behaviour. They conclude that inflows lead to greater than proportional increases in total public expenditure in recipient countries, and aid can be associated with reductions in tax. The volatile nature of aid can affect the macroeconomic fundamentals in countries that depend profoundly on foreign aid flows, by controlling for uncertainty. Selaya and Thiele (2010) explained that contradictions in the previous findings of the effectiveness of aid volatility can be attributed to the *"idiosyncratic characteristics of the recipient countries"*.

Outside this area in the disaggregated effect of volatility of aid, much of the literature goes in different paths. For instance, Fielding and Mavrotas (2005), argue that most of the literature discussing aid volatility focused on the aggregates for aid and this is a disadvantage in the analysis of aid volatility. For that they targeted the volatility of aid inflows by specifically studying two types of aid which have different kinds of volatility, namely sector-specific aid and non-sectoral allocated aid which together contributed for 95 per cent of total aid flows. Bourguignon and Sundberg (2006) discussed aid from the context of the absorptive capacity to reach the MDG goals. They discussed the effect of aid inflows from a macroeconomic perspective. Aid causes a distortion in the domestic prices in favour of non-tradable goods, which leads to a reduction in the purchasing power of aid. Neanidis and Varvarigos (2009) disaggregated aid into short impact aid, long impact aid and humanitarian aid to show that there are different kinds of aid that affect growth in the short term, while other kinds of aid show a slow impact on growth and find that aid disbursements targeted at productive purposes have a positive effect on growth, whereas *"pure transfers reduce growth"* (Neanidis and Varvarigos, 2009, p.455), and volatility affects these two influences. Fielding and Mavrotas (2008), in their study, explored the interaction between weak institutions and policies in the recipient countries and the effect of volatility of aid on sectoral aid, programme aid and emergency aid, to conclude that aid depends on both characteristics of donors and recipients.

The literature widely covers the effect of aid and aid volatility on growth. The debate on the effectiveness of official development assistance (ODA) considered the macroeconomic impact of the total development assistance. Very few studies disaggregate the targeted aid and study the effect of the sectoral aid on the outcome of this sector as a public service, most of which covered the health sector. Hudson (2012) states that the targeted aid exceeds its effectiveness from the macroeconomic aspect of the economy, to the individual aspect by the spill over effect of sectoral development on other sectors in the economy, and that the reallocation of aid for one sector on the account of another will result in annulling the effect of aid for both sectors, as both sectors will be subjected to positive or negative volatility. In the previous chapters, we explored how the water withdrawal for one sector has a spill over positive effect on the productivity of other sectors which is consistent with the effect of aid to improve targeted sectors, which is water and sanitation. Generally, the concern about the exploration of the effectiveness of aid for sectors and subsectors started after the pressing need to monitor the achievement of the MDGs (WHO, 2008). Beginning with the statement from Hudson and Mosley (2008), the volatility of aid or the instability of aid flows can cause harm for both investment and development as well by creating an uncertainty about the policies and the general atmosphere of investments. Also it can hamper the unaccomplished or half-finished sectorial project, which makes volatility of aid a tool that phases out the effectiveness of the sectoral aid and the delivery of public services that are financed by foreign aid. Moreover, they stated that the volatility of aid depends on the type of aid, and may vary between short run or reactive aid which is a reaction to emergencies and that tends to be more volatile than planned aid accompanied with planned disbursement.

Additionally, Hudson and Mosley (2008b) found by exploring the impact of aid volatility on the GDP/GNP shares of expenditure that negative volatility of aid affects government expenditure and positive volatility reduces investment and government expenditure shares. This finding reflects that a negative effect on sectorial development and public services can take place. Moreover, most studies examined aid volatility as an aggregate of aid from different perspectives, ignoring the effect of aid volatility on particular sector; Fielding and Mavrotas (2005) run an empirical analysis for 66 countries with an attempt to disaggregate aid values for different types of aid disbursement as sector aid, programme aid and emergency aid. In another work Fielding and Mavrotas (2008) conclude that the causes that affect sector aid volatility are not the same as the factors that affect total aid volatility. Lu *et al.* (2010) used a model that correlates overall Government spending on health with absolute levels of aid for the developing countries. They run panel data analysis methods to estimate the association between government domestic spending on health and GDP. But the results are biased due to increases in government spending being a short run process, as argued by Stuckler *et al.* (2011) who focus on volatility with respect to health, finding that each $1 of new aid is accompanied by only $0.37 of increased health spending. This can be due to "macroeconomic policy recommendations from financial institutions". They noticed that there was no additional benefit of external health aid for IMF-borrowing countries, while in countries that did not borrow from the IMF each additional $1 of aid is accompanied with $0.45 added to the health system.

5.3.2 Effect of aid volatility on access to safe water and sanitation: MDG goals

Many pieces of work focused on the costs and the benefits of the development of water and sanitation sector and its impact on improving the health sector (Hutton and Haller, 2004; Hutton *et al*. 2007). Getting to the crux of our study, the focus of our analysis is the importance of financing water and sanitation and to explore the impact of given aid on the improvement of this sector specifically to attain the MDG target for water and sanitation. Only one present part of the literature by Wolf (2007) has discussed the ODA effectiveness and the effect of volatility of aid on the safe access for *water and sanitation*, which is analysing the public service delivery. Wolf (2007) examines the effect of volatility of aid on education, health, water and sanitation to conclude that aid volatility shows better outcomes in sanitation, water and infant mortality. Wolf finds the share of official development assistance (ODA) for education and health seems to have a positive impact on outcomes in these sectors, while the total aid seems to have a negative impact. She measures aid volatility as the coefficient of variation for total aid between 1980 and 2002, whilst the regressions themselves relate to just 2002, and it questionable as to whether this reflects the concept of volatility as used in the literature.

The outcome of aid for water and sanitation are the indicators 30 and 31 used by the United Nations that determine the percentage of population with safe access to water and sanitation. We need to explore the effect of aid volatility on the proportion of the population with safe access to water and sanitation. Several constraints must be taken into consideration in dealing with this topic, which include the skilled workers needed for the disbursement of this kind of aid, the amount of physical capital and the current infrastructure. Also relevant are the current planning and policies that set a benchmark for public service development and delivery, reflecting the fact that water and sanitation are both important public goods.

5.4 The link between the MDG target for water and sanitation and the macroeconomy

Agénor *et al*. (2006) introduced a model to develop a macroeconomic method that links aid and public investment and explains some strategies that are available for poverty reduction. They developed this model to assess the improvement in the achievement of the MDGs in Sub-Saharan Africa. The effect of water on the economic development is discussed widely, and the demand on water by different economic sectors is affected in one way or another by the macroeconomic strategies and policies that enhance the national economy within the individual country. This fact enhances the developing countries which seek economic development through the channel of globalization to be aware of the effect of investment in the public sector, also to be aware that water and sanitation is a prerequisite for this development. As long as water as an input for production and sanitation is important for health issues, investments in these two subsectors are becoming more and more critical for development. Moreover, the Human Development report (2006) linked the availability of water with poverty reduction and human development, adding to the fact that the MDGs were established as targets to reduce poverty.

The link between the MDGs and the macroeconomic indicators is a topic for concern. Governments of the aid recipient countries are expected to show improvements in fiscal policy, and a better public service delivery is expected within the country that generates better public sector revenues and tax reforms. These are capable of improving growth and consequently alleviating poverty. As for public services, budgetary priorities vary from country to country and similarly for water and the sanitation sector. The constraint here is the lack of data on public expenditure for the water and sanitation sector. As for the macroeconomy , two factors govern the effectiveness of aid for these two sectors, water and sanitation, the absorptive capacity of aid and how it affects the macroeconomic performance within the country especially in the medium run and the adjustment of costs in the short run (WHO, 2004). The MDG indicators are framed in a way that they are linked, for example, poverty reduction, malnutrition, the health sector, education and infant mortality are directly linked to safe water and sanitation. Our focus in this study is on aid for water and sanitation; we choose a poverty indicator to illustrate its effectiveness with W&S MDG indicators. The inter links between the goals and the macroeconomic indicators that affect the single country are shown in Figure (5.3).

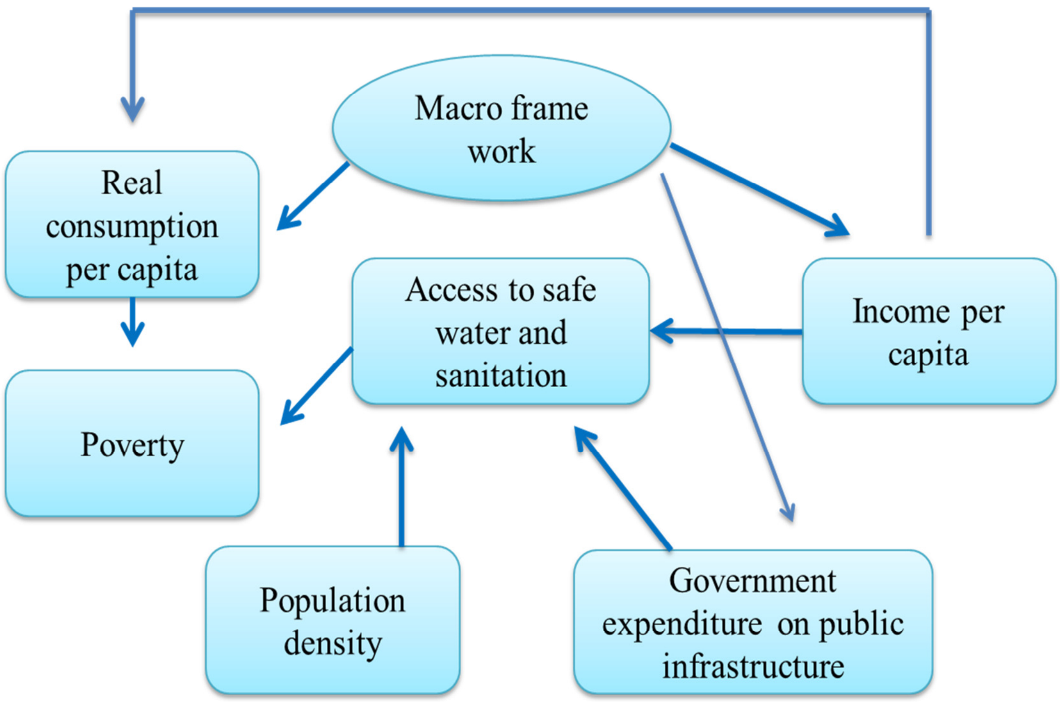

Figure 5.3: The link between the MDG and the macroeconomic framework

5.5 Role of donors for water and sanitation in reaching the MDG goals

Although the intentions to meet the required MDGs have raised the sectoral aid from 20 percent between 1990-1992 (only 4.9% distributed for water supply and sanitation) to 35 percent between 2002-2004 (only 3.9% allocated for water and sanitation), the allocated aid was biased to social aims rather than infrastructural targets.

5.5.1 Role of policies and institutions on ODA

Zetland (2010) highlights the fact that although the ODA increased during the last decade, monitoring the results and the feedback by donors is not covered enough with respect to the politics, where allocating ODA plays a part in interfering in domestic politics. Mavrotas and Ouattara (2007) stated that when donors have more control on project financing, there is a better growth in the recipient countries. However, donors' priorities are not always the same as recipient priorities, which may affect the volatility of aid. According to Hudson and Mosley (2008a), donors tend to show a coordination impact in their aid for certain countries. Dreher *et al.* (2008) conduct a panel data analysis for 143 countries over the period 1973-2002 for a disaggregated data set on aid to speculate whether or not aid is used as a mean to foster political support by the recipients in their voting in the UN General Assembly. They conclude that grants and untied aid are shaping the UN voting behaviour. Some donors take into account economic policy, institutional stability and the poverty index in the recipient countries. Some donors on the other hand, focus on the objectivity of aid in line with their own targets. That being the case for the donors' part reflects how donating aid can have political goals.

From the recipient's perspective, the effectiveness of aid in the recipient countries is found by different researchers to be highly relevant to the political behaviour of the recipient. Aid sometimes needs institutional reforms to make it work, for the negative impact of aid volatility may act as a stimulating factor for policy reforms in the recipient countries (Hudson and Mosley, 2008a and Hudson, 2012). The donors' reactions to the political, governance and economic performance and management in the recipient countries can stimulate aid volatility in those countries. Hudson (2012) explains how donors tend to maximize their welfare function subject to a budget constraint. Also, donors know that volatility affects negatively both on the recipient country and their own credibility as a donor. Volatility may be a response to recipient policies and behaviour. Disbursement of aid can be decreased due to political interventions. Also, aid budgets can be subjected to a leakage due to emergency priorities. In addition, displacement or switching between sectors can be biased by donors' preferences. Hudson comments that *"This can occur in response to an emergency in the country or unforeseen developments possibly associated with existing aid spending. However, as already indicated, having diverted aid away from sector j in period t, the donor may respond by increasing it above trend in the following period and vice versa in a sector which saw an aid surge. In this way aid shocks can have ripple effects. In addition aid between sectors may be complementary, for example, increasing humanitarian aid may foretell an increase in programme assistance aid".* Levin and Dollar (2005) studied the effectiveness of aid by making a comparison between the countries with strong institutions and those with weak ones and finds that aid needs more time to show its results in countries with weak institutions.

In line with the Global Green New Deal (Barbier, 2010), the G20[29] group were aware of the importance of safe drinking water and sanitation for an economic development, not only for the vulnerable places in the world but also for the members of the G20 since the group itself accounts for 70% of population without proper sanitation and more than 50% without safe access to water resource (UNICEF, 2001; Schuster-Wallace *et al*., 2008).

From another perspective, the responsibility for safe access to water and sanitation within the individual country is a shared responsibility. But the ultimate responsibility partly lies with the current governments and the applied effective

[29] The Group of Twenty, or G20, is the premier forum for international cooperation on the most important aspects of the international economic and financial agenda. It brings together the world's major advanced and emerging economies. G20 memebers are: Argentina, Australia, Brazil, Canada, China, European Union, France, Germany, India, Indonesia, Italy, Japan, Mexico, Russia, Saudi Arabia, South Africa, South Korea, Turkey, United Kingdom and the United States.

policies that stimulate and ascertain an efficient delivery for the public goods. We can notice from figure (5.4) that the moving trend of total aid is largely determined by the bilateral aid for the highest bilateral donors (Denmark, France, Germany, Japan, Netherlands, Norway, Sweden, Uk, USA). From figure (5.5) we can see that Japan is the highest bilateral donor for water and sanitation (20% of aid to water in 2005-2006). Japan accounted for 27% of water and sanitation aid between 2007-2008. Some donors such as France and UK are more interested in donating to previous colonies (Alesina and Dollar, 2000).

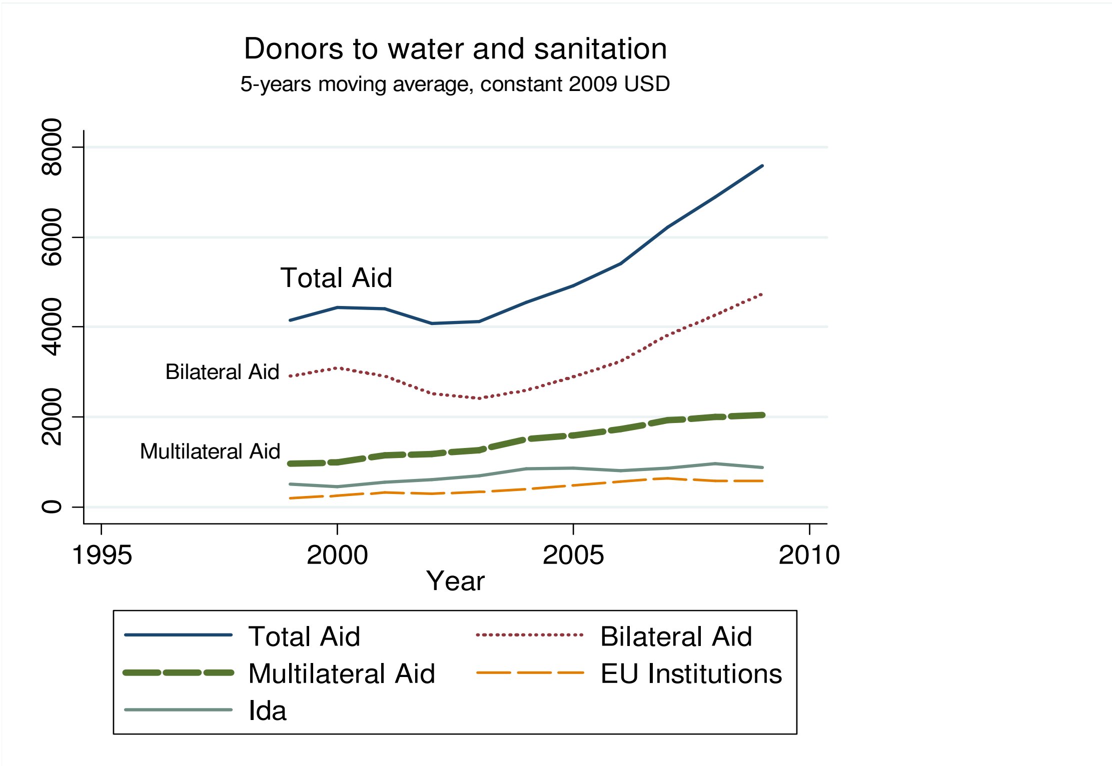

Figure 5.4: Five years MA for commitments for water and sanitation for all donors. Source of data from DAC- CRS

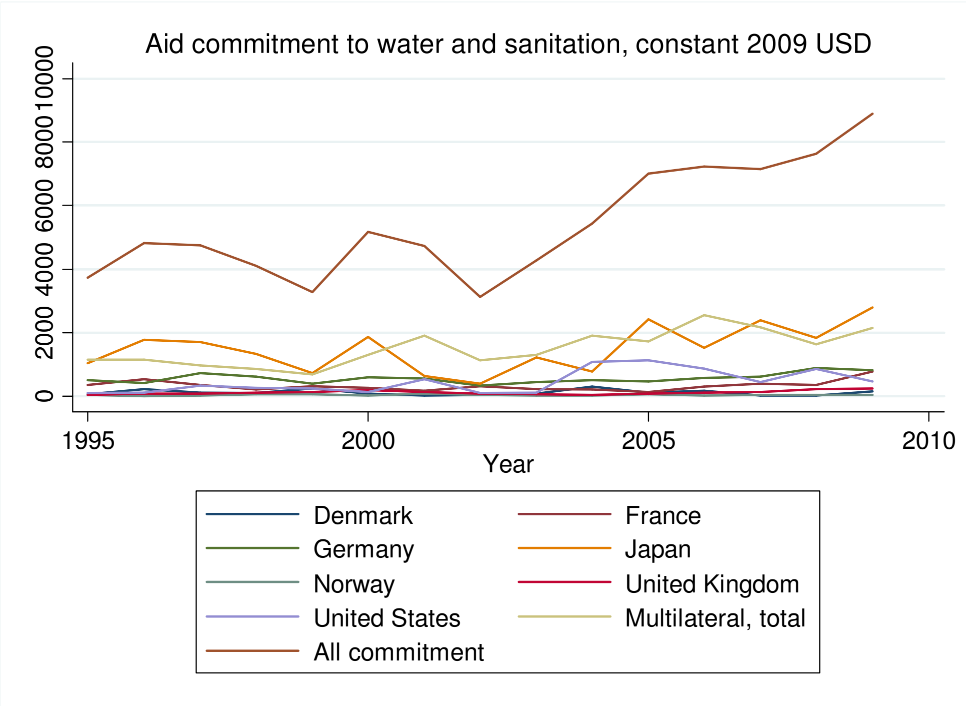

Figure 5.5: Five years MA for commitments for water and sanitation by biggest bilateral and multilateral donors. Source of data from DAC- CRS

5.6 Methodology and analysis

5.6.1 Safe access to water and sanitation: Aid effectiveness in Recipient countries

In general, building upon Hudson (2012), we are analysing the aid volatility for one sector, which is water and sanitation aid, and the outcome of this sectoral aid in our study is the safe access to water and sanitation as well. The share of population with access to safe water is a function of population density, real income per capita and public spending on infrastructure (Agénor *et al*. 2006).

$$S_{it} = f(ODA, \Phi ODA, P, g, I, X_i) \qquad (5.1)$$

Where S is the safe access to water and sanitation for country *i* during period *t*, *ODA* is the aid for water and sanitation, ΦODA is the volatility of aid, p is the policies, g is the geographical determinant, I is the income per capita, X represents the remaining variables that affect the output as safe access to W&S.
Where aid volatility can be expressed in this case as

$$\Phi ODA = \frac{\Delta S_{it}}{\Delta ODA} \tag{5.2}$$

5.6.1.1 Data

We are analysing several socioeconomic factors and the effect of aid on the outcome of target 10 of the MDGs. We use several databases for the analysis purposes. The data are defined and summarized in table (5.2). The outcome of target 10 is proxied by the proportion of population with safe access to water (MDG indicators from the UN website). Data on safe water and sanitation for the MDGs is obtained from the official United Nations site for the MDG indicators which is derived from the WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation. It is defined as the *proportion of population with sustainable access to an improved water source, urban and rural*, as the percentage of the population[30]. The WHO use any of the following types of water supply for drinking: piped water, public tap, borehole or pump, protected well, protected spring or rainwater. Improved water sources do not include vendor-provided water, bottled water, tanker trucks or unprotected wells and springs. As for sanitation it is added as the proportion of population with access to improved sanitation.

The aid data for water and sanitation is obtained from Creditor Reporting System (CRS)-Development Assistance Committee (DAC) database on aid commitments and disbursements at a constant USD 2010 million for the total water and sanitation.

[30] Access to improved sanitation facilities refers to the percentage of the population with at least adequate access to excreta disposal facilities that can effectively prevent human, animal, and insect contact with excreta. Improved facilities range from simple but protected pit latrines to flush toilets with a sewerage connection. To be effective, facilities must be correctly constructed and properly maintained. World Health Organization and United Nations Children's Fund, Joint Measurement Programme (JMP) (http://www.wssinfo.org) (Accessed June 2012).

The DAC data relate to activities that have water supply and sanitation as their main purpose. We collected the main bilateral donorś data, the multilateral donorś data as well as commitments[31]in constant USD 2010 million. From the World Bank's World Development Indicators (WDI), we have collected:

The World Bank governance indicators[32] provided by the World Bank website, including government effectiveness, rule of law, and Political Stability and Absence of Violence/Terrorism (1996-2010). Estimate of governance (ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance). Net ODA received as a percentage of GNI due to availability of observations. The GDP per capita in constant USD. In addition we include the population density due to the effect of this and urbanization on further infrastructure and more water delivery for households and different economic sectors. We expect infrastructure costs to decline with population density.

Gross national expenditure as a % of GDP is included due to a number of different reasons. First of all Mosley et al. (1987) commented on different modes for the impact of aid, which can be direct by disbursements from the donors, or can be *indirect* through governmental spending of the recipient country on the development of the public sector which is related to the policies applied by the recipient governments. The second reason for using this specification is the lack of data for water and sanitation public governmental spending in the recipient countries. We added the gross national expenditure as a percentage of GDP to represent the allocation of inputs especially the direct governmental inputs that determine the public spending and the amount of output which is generally hard to estimate. Here in this study it is estimated as the percentage of population with safe access to W&S. Also, to examine the effect of government's investment on this particular sector, Celasun and Walliser (2008) have debated that unpredicted aid shortages can force governments to cut public investment and that differs from one government to

[31] A commitment is a firm written obligation by a government or official agency, backed by the appropriation or availability of the necessary funds, to provide resources of a specified amount under specified financial terms and conditions and for specified purposes for the benefit of a recipient country or a multilateral agency. (CRS- DAC definition).

[32] Estimate of governance (ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance).

another depending on the government's strategy for the annual national budget. Eventually, it stands for the total expenditure of all kinds within the economy, public and private.

Because of its impacts on a range of diseases, target10 in the MDGs is a health impact target. We added the infant mortality rate as a conceptual indicator that stands for the effect of aid on the health sector in its spill over effect on the advancement in the water and sanitation sectors, our target of analysis. Finally, aid volatility is determined as the mean of the square of the error term from regressing aid disbursements on a trend and trend squared for each country. If predicted aid from this regression is negative, then a lower bound of zero is imposed and the error adjusted accordingly (Hudson, 2012). We added a dummy variable for tropical countries, the tropical country takes the number 1 and the non-tropical are represented by 0. Two reasons behind the addition of the tropical dummy is the fact that tropical countries show underdevelopment (Sachs, 2001). The second reason is the recent literature that outlined the poor outcome of aid in tropical regions (Lensink and White, 2001; Dalgaard and Hansen, 2001; Hansen and Tarp, (2000, 2001)).

Table 5.2: The summary of data

Variable	Definition and source
Percentage of population with safe access to improved water	The proportion of population with sustainable access to an improved water source, urban and rural (in percentage)
Percentage of population with proper access to improved sanitation	The proportion of population with sustainable access to an improved water source, urban and rural (in percentage)
ODA W&S	ODA for water and sanitation (CRS- DAC database) (constant USD 2010)
Aid volatility	Regressing aid disbursement on time trend and its square for each country to calculate the predicted value. Then calculate the difference between aid and this predicted value for each country and its square used for volatility[33].
Gross national expenditure (% of GDP)	Gross national expenditure (formerly domestic absorption) is the sum of household final consumption expenditure (formerly private consumption), general government final consumption expenditure (formerly general government consumption), and gross capital formation (formerly gross domestic investment). (source: World Bank development indicators)
Net ODA received (% of GNI)	Net official development assistance (ODA) consists of disbursements of loans made on concessional terms (net of repayments of principal) and grants by official agencies of the members of the Development Assistance Committee (DAC), by multilateral institutions, and by non-DAC countries to promote economic development and welfare in countries and territories in the DAC list of ODA recipients. It includes loans with a grant element of at least 25 percent (calculated at a rate of discount of 10 per cent). (source: World Bank development indicators)
Infant mortality rate	Infant mortality rate is the number of infants dying before reaching one year of age, per 1,000 live births in a given year. (source: World Bank development indicators)
Government effectiveness	Reflects perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies. Estimate of governance (ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance) (source: World Bank development indicators)
Rule of law	Reflects perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence. Estimate of governance (ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance) (source: World Bank development indicators)
Political stability and absence of violence index	Reflects perceptions of the likelihood that the government will be destabilized or overthrown by unconstitutional or violent means, including politically-motivated violence and terrorism. Estimate of governance (ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance) (source: World Bank development indicators)

[33] We do not have enough observations (2002-2010) and hence we use this method which in any case would on a small sample give similar results to the Hodrick–Prescott filter.

5.6.2 Analysis of Recipients

We analyse the effect of aid and aid volatility and other socioeconomic factors with a longitudinal data for 139 countries listed in appendix 5.III, the models of country i at time t:

$\Delta Swater_{it}$= f(aid$_{it}$/GDP per capita, ΦODA_{it}, time dummy variables for individual countries$_{it}$) (5.3)

$S\ water_{it}$= f(Infant mortality, Net ODA as a % of GNI$_{it}$, lGDP per capita, Population density, Gross national expenditure as % of GDP, Governance variables$_{it}$) (5.4)

$S\ water_{it}$= f(aid$_{it}$/GDP per capita, ΦODA_{it},Infant mortality$_{it}$, Net oda as% GNI$_{it}$, lGDP per capita$_{it}$, Population density$_{it}$, Gross national expenditure as % of GDP$_{it}$, Governance variables$_{it}$) (5.5)

$\Delta Ssanitation_{it}$= f(aid$_{it}$/GDP per capita, ΦODA_{it}, time dummy variables for individual countries$_{it}$) (5.6)

$S\ sanitation_{it}$= f(Infant mortality, Net oda as% GNI$_{it}$, lGDP per capita, Population density, Gross national expenditure as % of GDP, Governance variables$_{it}$) (5.7)

$S\ sanitation_{it}$= f(aid$_{it}$/GDP per capita, ΦODA_{it}, Infant mortality$_{it}$, Net oda as% GNI$_{it}$, lGDP per capita$_{it}$, Population density$_{it}$, Gross national expenditure as % of GDP$_{it}$, Governance variables$_{it}$) (5.8)

The regression results are included in tables 5.3 through 5.9. Our analysis is based on three parts; first part is to explore the effectiveness of aid and aid volatility in the change of the safe access to water and sanitation for the recipient countries and the different factors that affect safe access to water and sanitation. The second is to explore the effectiveness of the aid with respect to the donors in order to reach the MDG goals, while the third part is a multilevel analysis of the region’s effect on the outcome of aid on water and sanitation.

The collinearity test indicates a presence of collinearity between several variables of estimation[34], heteroskedacticity test[35] rejects the null that the variance is fixed and accept the alternative that there is heteroskedacticity, for that we use the feasible generalized least squares. We run the cross sectional times series analysis with feasible generalized least square (see the appendix 5.I). FGLS is a variance covariance method using the independent autocorrelation structure. We did not report the R squared for the GLS regression as *"When you estimate the model's parameters using generalized least squares (GLS), the total sum of squares cannot be broken down in the same way as in OLS, making the R-squared statistic less useful as a diagnostic tool for GLS regressions"* (McDowell, 2003).

Access to water and access to sanitation are treated as endogenous variables. Water supply and sanitation are public goods imperfect substitute goods which are affected by several factors that may interact with aid for this sector as we can see with the negative sign that appeared in Wolf´s (2007) results. We could not represent the interaction that takes place between aid and several variables that affect the results of the regression and could not capture the effect of aid without interfering with this interaction on the signs of the coefficients, because of that we chose to run two panels for each dependent variable. The reason is to explore the effect of our variables of interest through two channels; one channel is the direct effect of aid on water and sanitation and the volatility of this aid on the change of the safe access together with the time year dummies for each recipient country. The second panel is

[34]In the correlation matrix or covariance matrix for a group of variables the collinearity between the aid and the aid volatility is more than 0.5, between the GDp per capita and the safe access to water 0.7, between GDP per capita and the governance variables is higher than 0.6, the correlation between the safe access to sanitation and the GDP per capita is 0.7092, between rule of law and government effectiveness is 0.8527. Also, we use the Likelihood-ratio test (Wooldridge, 2002) by taking advantage of heteroskedastic iterated GLS that produces maximum-likelihood parameter estimates which is obtained by fitting the model with panel- level heteroskedasticity and then save the likelihood (infers the number of constraints when we fit nested models by looking at the number of parameters estimated), next step is fitting the model another time without heteroskedasticity in this case the panel-level variances are estimated as nuisance parameters, and their count is not included in the parameters estimated. The chi-square appears to support the hypothesis that IGLS model does have panel-level heteroscedascity. LR chi^2 (120)= 1433.50*** for safe access to water ratio and LR chi^2(120)= 1257.42*** for safe access to proper sanitation equation.

[35] Breusch-Pagan / Cook-Weisberg test for heteroskedasticity (Ho: Constant variance) the chi squared is 206***for safe access to water equation and 197.63*** for access to improved sanitation equation.
We use Wooldridge test for autocorrelation in panel data (Drukker, 2003). Wooldridge test for autocorrelation in panel data is F(1,115) = 306.166*** (H_0: no first-order autocorrelation) for safe access to water equation and F(1,115) = 55.111***(H_0: no first-order autocorrelation) for safe access to proper sanitation.

to model the effect of various socioeconomic variables that affect the development and growth for safe access to water and sanitation. These factors also trigger the demand for improved sources of water and sanitation and may interact with the direct effect of aid.

In part I of the regression, we use the aid disbursement data (constant USD 2010) to analyse the effect of aid and aid volatility on safe access to water and to proper sanitation in the recipient countries. The disbursement data is available from 2002 which is consistent with the following facts. Firstly aid is increased after the announcement of the MDGs in 2000. Secondly O'Hara *et al*. (2008), who conduct a survey for Kazakhstan, conclude that the year 1990 is not an appropriate baseline year to assess the improvement in the MDG goals.

The regression results for each one of the dependent variables:

1-*Percentage of population with safe access to improved water:*

We express the full impact of aid in our model by a specification (ODA W&S/GDP). See the results in tables 5.3 and 5.5 for the all recipient countries and for low income countries[36]. The aid disbursement for W&S is represented as aid disbursement per GDP and is found to be significant at a 1% significant level for all of the recipient countries. The accumulated effect of aid is associated with approximately a 8.7% (0.087=exp (0.083)-1) positive progress in population with access to improved water source. As results indicate in table 5.3 (column 5), aid for rural areas leads to a significant increase of 10.4% in safe access to water in rural areas, and a 2.4 % increase in urban areas. Aid volatility is found to be significant for all recipient countries. Where the provision of aid increases by 1 % we can see that safe access to water slows down by 0.5% (=exp (-0.0046)-1) in urban areas and by 1.4% in rural areas. Moving to the effect on the low income countries (Table 5.5), aid and aid volatility are significant in both their effect on all the low income countries in our panel and for the rural areas in these countries. This means aid works when targeting

[36] The World Bank classifies low income countries as countries that have GNI per capita of US$1,005 or less.

rural areas by improving safe access to water by 6% since 2002 so far. Considering the effect of different socioeconomic variables that may affect safe access to water, it is apparent that the spill over of aid for health sector has a positive significant effect on the increase in the safe access to water, that is represented by infant mortality rate, which is significant for all recipient countries, for their rural and urban access to water, A decrease of infant mortality[37] by 1% indicating that access to improved water has increased by 30% (=exp (-0.358)-1) for recipient countries while this percentage increases to 40% for rural areas in recipient countries, the significant results appear for the results are apparent for urban and rural areas for low income countries. The impact of aid is consistent for the fixed effects model (column 7) for all countries and for the low income countries, which asserts the positive impact of aid within the individual country.

Net ODA as a % of GNI is negatively significant at the 10% significant level for rural areas in all recipient countries. This is consistent with absorptive capacity with high aid elsewhere pulling resources away from water and sanitation towards other projects. Also, the global interest of the donors and the official aid were concentrated highly on health and education with a lower allocation of the ODA to other sectors which is apparent in the results, that is previously mentioned in an Off-track, Off-target (2011, p.5) report *"In Sub-Saharan Africa, access to sanitation is now the most off-track 2015 Millennium Development Goal (MDG) target. On current trends it will not be met for two centuries. In developing countries, spending on water, sanitation and hygiene services is minimal compared to health and education, and the share of aid flows going to water and sanitation has fallen over the last 15 years. The unforeseen impact is that slow progress on this essential foundation for broader human development is holding back progress in health and education, despite increased spending in those areas. Furthermore, lack of access to water and sanitation is a major drag on economic growth, and costs African and Asian countries up to 6% of their Gross Domestic Product (GDP) each year"*. This also can be explained by the behaviour of the authorities in the recipient countries that aid can

[37] We had a concern about the endogeneity of Infant mortality with the safe access to water indicator, we rerun the regression after dropping infant mortality from the model which did not affect on the significant or the coefficients of the results.

be non-effective in some sectors due to the political interference in the allocation of the coming resources. While at the same time it is effective for the urban areas in the low income countries (Column 6 - table 5.5). Gross national expenditure with the access to improved water is significant and positive for the rural areas in all recipient countries, while it is negative for urban water subsectors. This can be due to the donors influence on governments to increase spending for the public sector in the rural areas as a side effect to expanding spending to reach the MDG goals in alleviating poverty in the poorest areas. Another reason can be the lack of development projects in the rural areas can direct funds to rural areas. The same effect can be found in the results of the low income countries (column 4- table 5.5). Of course in addition, developing countries themselves may care about their rural areas.

As for the positive effect of the population density on the outcome of the target (safe access), a 1% increase in population density triggers an improvement in the water subsector by 25%, by 4% for urban areas and by 61 % for the rural areas. The effect is apparent as well for the low income countries where a 1% increase in population density leads to a 46% increase in water infrastructure and improvement. This reduces to a 4% increase for urban areas, and for rural areas reaches 87%. This is also in agreement with the postulation given by Agénor *et al*. (2006) who stated that costs of installing bigger infrastructure decreases with higher population density. It is cheaper and easier to provide water and sanitation infrastructure to a densely populated country. Another perspective is that, higher population density reduces the costs of providing water infrastructure.

The positive impact of the GDP per capita is in parallel with the theme that economic growth and economic development usually is a cause of improved public sector delivery. We can see from the tables that a 1% increase in GDP per capita increases the access to safe and improved water by 0.1 % for all the recipient countries, and by 0.2% for the low income countries.

The rule of law which is a governance indicator shows a significant positive effect on water access in the urban areas for all the recipients and the low income countries as well, which indicates that as rule of law increases by 1 % the safe access to water increases by 12% for the low income countries and by 7.8% for their urban areas. To put it another way, the mean of the rule of law is zero, if we move, if it increases from zero to 1, then the safe access increases by 78%. While at the same time, it is apparent that government effectiveness and political stability play a falling role in development of these sub sectors for countries receiving aid for water and sanitation, that is obvious from the negative signs accompanied with the regression coefficients, Neumayer (2003, p.9) mentioned that existing literature is undogmatic that aid boosts growth in the presence of good governance. For more emphasis, we rerun the regressions without the political stability and find that the regression results and the significant impact did not change for the rest of the variable. The dummy variable for tropics is negative and significant at a 1% significance level in most of the results, which is consistent with the previous literature that discussed how aid and development efforts are not very effective in tropical areas (Sachs, 2001). Also, it seems that aid for water and sanitation is working for all countries, but still there is a problem with safe access for tropical countries where efforts must increase more.

Column (1) shows the impact of aid and aid volatility on access to water. This impact will be largely seen through the impact of other variables such as infant mortality (through the channel of the effect of aid targeting the health sector), political stability, and the rest of the variables included in the regression. When we include variables of both columns (1) and (2) in one regression, it becomes more difficult to get both significant. We can do this for the full sample of countries and with the fixed effects (column 7). The main problem is the change in the sign of population density. Recall our earlier argument that with the fixed effects the coefficients are reflecting short term changes. Thus overall results (for countries who receive ODA for water and sanitation column 7 in table 5.3 and for the low income countries column 7 in table 5.5 suggest that more densely populated countries have better developed water infrastructure. But an increase in population density can have a short term adverse effect.

2-*Percentage of population with safe access to sanitation:*

From (columns 1, 3, 5 and 7 - table 5.4) we can see that the aid for W&S per GDP is positive and significant for all the recipient countries, for rural and urban areas as well, an increase in ODA per GDP leads to a 18 % positive improvement in safe access to sanitation in all the recipient countries, 9 % for urban areas and a 21 % for rural areas as well. For the low income countries the percentage change in improvement is 8.6% for the all the income countries, while for the rural areas the improved sanitation increases by 11.6% for every 1% increase in allocated aid. Also we can see the significant effect of aid on all the variables, the aid, aid volatility and the socio economic variables in the fixed effect regression, the results are included in column 7 in table 5.4 for the recipient countries and column 7 in table 5.6 for the low income recipient countries.

Infant mortality, on the other hand is consistent with the *spill over* effect of aid for the health sector leading to improvement in the public sector, where a 1% decrease in infant mortality is associated with a 63.8% increase of improved sanitation, while this reaches 66% for the low income countries. We can see from the tables 5.4 and 5.6 that a decrease in infant mortality is associated with improved sanitation facilities in the rural and the urban areas for all the recipients and for the low income countries.

Gross national expenditure as % of GDP is significant and negative for access to sanitation for the low income countries where that gives evidence that most low income countries 'governments have a low interest in investing for sanitation especially in the rural areas, where the development of this subsector is encouraged by the outside sources of funds. A high share of government spending in GDP may reflect economic and political ambitions to drive the country forward, ambitions for which rural areas play no great part. Sridhar and Woods (2010) found that the development assistance provided for governments in the recipient countries has a negative effect on government spending on health and conclude that aid for health is not transferred by governments. At the same time ODA directed to private nongovernmental organizations (NGOs) proved to have a positive effect on government spending which means funding should be delivered via private channels. Our regression analysis indicates that there is a positive effect of public spending on safe access to both water and sanitation. Another alternative view is that it could be argued that the private sector is more efficient than the public sector and a high value for this variable signals a large public sector which delivers water inefficiently.

The controversial issue here is the significance and the negative sign of the Political stability and absence of violence index, where we can conclude that most of the countries that receive this aid and fall back in improved water and sanitation have a low level of governance. In both types of safe access, the governance indicators show a negative and less effectiveness in these subsectors which is discussed by Fielding and Mavrotas (2008) who specifies that volatility affects sectoral aid in different ways as to have it affects other aid and usually the effect of volatility for sectoral aid is higher in recipient countries with weak institutions and policies.

Finally, we rerun the regressions using dummy variables for policies starting from year 2000; the dummies fail to be significant. The lack of significance of the dummy variables leads us to conclude that there is no evidence that the MDG's have changed the behaviour of either the donors or the recipientś governments. But two clarifications need to be made. Firstly, we have relatively little data prior to the MDGs. Secondly; donors may have anticipated the MDGs in the early years. That calls for the need to investigate the donors behaviour that we are exploring in the next section.

Table 5.3: Regression of safe access to water

	Change in safe access to water	Safe access to water	Change in safe access to urban water	Safe access to urban water	Change in safe access to rural water	Safe access to rural water	Safe access to water/ Fixed effect
Variable	Column(1)	Column(2)	Column(3)	Column(4)	Column(5)	Column(6)	Column(7)
Constant	0.005	3.859***	0.0025*	4.714***	0.007	3.683***	4.284***
	(1.33)	(46.68)	(2.12)	(93.41)	(1.23)	(31.78)	(56.95)
Oda W&S/GDP	0.083***		0.024***		0.099***		0.105***
	(4.52)		(4.38)		(3.38)		(3.95)
Aid volatility	-0.014**		-0.0046**		-0.014		(0.007)
	(2.75)		(3.05)		(1.71)		0.49
Time dummies	Yes	No	Yes	No	Yes	No	No
Infant mortality		-0.358***		-0.215***		-0.509***	-0.494***
		(14.61)		(14.15)		(14.8)	(16.04)
Net oda as% gni		-0.110		-0.004		-1.676*	-0.015
		(0.2)		(0.01)		(2.14)	(0.13)
lGDP per capita		0.083***		-0.003		0.069***	0.050***
		(10.71)		(0.58)		(6.43)	(5.7)
Population density		0.227***		0.039*		0.478***	-0.649***
		(7.33)		(2.03)		(11.03)	(3.91)
Dummy for Tropical countries		-0.099***		-0.053***		-0.123***	No
		(9.54)		(8.15)		(8.41)	.
Government effectiveness		-0.021		0.002		0.009	-0.008
		(1.27)		(0.2)		(0.41)	(1.34)
Rule of law		0.019		0.0204*		0.011	0.008
		(1.19)		(2.02)		(0.48)	(1.33)
Political stability and absence of violence index		-0.216**		-0.134**		-0.238*	-0.165***
		(2.82)		(2.84)		(2.22)	(4.85)
Gross national expenditure as % of GDP		1.053**		-0.4477*		2.964***	0.049
		(3.25)		(2.26)		(6.52)	(0.54)
N	976	1117	992	1135	979	1122	762
R^2							0.5353
R^2 adjusted							0.4395
Wald chi square	28.08***	2058.34***	20.58***	825.12***	21.74***	1834.34***	

t-statistics are in parentheses, *** significant at 1% level, ** significant at 5% level, * significant at 10% level. Column (1) through (6) are the FGLS regression results, Fixed effects for the effect of all the variables of interest on the safe access to water for the recipient countries are included in column (7).
We rerun the regression without infant mortality to check the endogeneity of this variable and the results did not change with signs and significance.

Table 5.4: Regression of safe access to proper sanitation

	Change in safe access to sanitation	Safe access to sanitation	Change in safe access to urban sanitation	Safe access to urban sanitation	Change in safe access to rural sanitation	Safe access to rural sanitation	Safe access to sanitation/ Fixed effects
Variable	Column(1)	Column(2)	Column(3)	Column(4)	Column(5)	Column(6)	Column(7)
Constant	0.007	2.651***	0.002	3.452***	0.0153**	2.795***	3.622***
	(1.32)	(12.67)	(0.44)	(19.84)	(2.85)	(8.2)	26.43
Oda W&S/GDP	0.171***		0.087***		0.195***		0.315***
	(6.61)		(4.5)		(7.81)		(6.5)
Aid volatility	-0.026***		-0.012*		-0.028***		-0.048
	(3.66)		(2.28)		(4.03)		(1.76)
Time dummies	Yes	No	Yes	No	Yes	No	No
Infant mortality		-1.012***		-0.757***		-1.573***	-0.657***
		(16.34)		(14.49)		(15.52)	(11.64)
Net oda as% gni		0.956		0.236		-0.209	0.343
		(0.68)		(0.2)		(0.09)	(1.57)
lGDP per capita		0.263***		0.152***		0.264***	0.083***
		(13.36)		(9.28)		(8.2)	(5.19)
Population density		0.451***		0.183**		0.863***	0.316
		(5.75)		(2.78)		(6.79)	(1.03)
Dummy for Tropical countries		-0.339***		-0.263***		-0.525***	No
		(12.89)		(11.9)		(12.32)	.
Government effectiveness		-0.0851*		-0.034		-0.166*	-0.004
		(2.08)		(0.99)		(2.51)	(0.37)
Rule of law		-0.107**		-0.104**		-0.063	0.024*
		(2.59)		(2.99)		(0.94)	(2.01)
Political stability and absence of violence index		-0.383*		-0.141		-0.832**	-0.248***
		(1.96)		(0.87)		(2.64)	(3.93)
Gross national expenditure as % of GDP		-0.115		1.095		-0.894	-0.098
		(0.14)		(1.62)		(0.68)	(0.6)
N	976	1115	997	1138	983	1124	762
R^2							0.483
R^2 adjusted							0.377
Wald chi square	46.16***	2400.01***	21.21***	1593.05***	68.77***	1706.76***	

t-statistics are in parentheses, *** significant at 1% level, ** significant at 5% level, * significant at 10% level. Column (1) through (6) are the FGLS regression results, Fixed effects for the effect of all the variables of interest on the proper access to sanitation for the recipient countries are included in column (7).
We rerun the regression without infant mortality to check the endogeneity of this variable and the results did not change with signs and significance.

Table 5.5: Regression of safe access to water for low income countries

	Change in safe access to water	Safe access to water	Change in safe access to urban water	Safe access to urban water	Change in safe access to rural water	Safe access to rural water	Safe access to water/ Fixed effect
Variable	Column(1)	Column(2)	Column(3)	Column(4)	Column(5)	Column(6)	Column(7)
Constant	-0.228***	2.981***	-0.053***	4.973***	-0.293***	2.235***	3.968***
	(8.18)	(11.4)	(3.39)	(31.88)	(7.59)	(6.21)	(25.59)
Oda W&S/GDP	0.535***		0.065		0.727***		0.075*
	(4.99)		(1.09)		(4.9)		(2.08)
Aid volatility	-0.342**		-0.027		-0.469**		0.023
	(2.64)		(0.37)		(2.62)		(0.73)
Time dummies	Yes	No	Yes	No	Yes	No	No
Infant mortality		-0.064		-0.134***		-0.178*	-0.574***
		(1.01)		(3.53)		(2.04)	(10.82)
Net oda as% gni		-0.365		1.373*		-2.732	0.112
		(0.35)		(2.23)		(1.92)	(0.67)
lGDP per capita		0.181***		-0.011		0.238***	0.121***
		(5.88)		(0.61)		(5.62)	5.9
Population density		0.380***		0.027		0.628***	-1.210***
		(5.64)		(0.68)		(6.77)	(4.78)
Dummy for Tropical countries		-0.196***		-0.104***		-0.161***	No
		(6.06)		(5.39)		(3.61)	
Government effectiveness		-0.106*		-0.030		-0.059	-0.014
		(2.38)		(1.13)		(0.96)	(1.44)
Rule of law		0.924*		0.579*		0.660	0.003
		(2.00)		(2.1)		(1.04)	(0.26)
Political stability and absence of violence index		-0.269		-0.148		-0.593*	-0.217***
		(1.34)		(1.24)		(2.14)	(3.51)
Gross national expenditure as % of GDP		2.401*		-2.612***		5.061***	0.005
		(2.45)		(4.47)		(3.75)	(0.03)
N	287	339	287	339	287	339	294
R^2							0.6408
R^2 adjusted							0.5579
Wald chi square	12.28***	299.85***	7.61***	135.75***	11.14***	305***	

t-statistics are in parentheses, *** significant at 1% level, ** significant at 5% level, * significant at 10% level. Column (1) through (6) are the FGLS regression results, Fixed effects for the effect of all the variables of interest on the safe access to water for the low income recipient countries are included in column (7).
We rerun the regression without infant mortality to check the endogeneity of this variable and the results did not change with signs and significance.

Table 5.6: Regression of safe access to sanitation for low income countries

	Change in safe access to sanitation	Safe access to sanitation	Change in safe access to urban sanitation	Safe access to urban sanitation	Change in safe access to rural sanitation	Safe access to rural sanitation	Safe access to sanitation/ Fixed effects
Variable	Column(1)	Column(2)	Column(3)	Column(4)	Column(5)	Column(6)	Column(7)
Constant	-0.457***	3.635***	-0.252***	2.822***	-0.564***	6.057***	3.181***
	(6.74)	(5.37)	(5.41)	(6.17)	(5.53)	(5.91)	(10.05)
Oda W&S/GDP	1.023***		0.765***		1.082**		0.318***
	(3.93)		(4.23)		(2.76)		(4.31)
Aid volatility	-0.567		-0.433*		-0.620		-0.075
	(1.8)		(1.97)		(1.31)		(1.16)
Time dummies	Yes	No	Yes	No	Yes	No	No
Infant mortality		-0.895***		-0.676***		-1.521***	-0.836***
		(5.46)		(6.12)		(6.12)	(7.72)
Net oda as% gni		6.568*		2.468		6.926	0.210
		(2.46)		(1.38)		(1.71)	(0.61)
lGDP per capita		0.228**		0.302***		0.018	0.135**
		(2.86)		(5.62)		(0.15)	(3.23)
Population density		0.316		-0.017		0.634*	-0.530
		(1.81)		(0.15)		(2.4)	(1.03)
Dummy for Tropical countries		-0.595***		-0.417***		-0.733***	No
		(7.09)		(7.35)		(5.77)	
Government effectiveness		-0.027		-0.126		-0.012	-0.012
		(0.23)		(1.62)		(0.07)	(0.58)
Rule of law		-0.091		-0.084		-0.033	0.038
		(0.76)		(1.04)		(0.18)	(1.62)
Political stability & absence of violence index		-0.256		0.130		-0.752	-0.403**
		(0.49)		(0.37)		(0.95)	(3.19)
Gross national expenditure as % of GDP		-6.026*		-0.968		-15.399***	0.108
		(2.38)		(0.57)		(4.01)	(0.38)
N	287	339	291	340	287	339	294
R^2							0.5287
R^2 adjusted							0.4198
Wald chi square	15.51***	329.40***	9.04***	388.85***	22.53***	272.51***	

t-statistics are in parentheses, *** significant at 1% level, ** significant at 5% level, * significant at 10% level. Column (1) through (6) are the FGLS regression results, Fixed effects for the effect of all the variables of interest on the proper access to sanitation for the low income recipient countries are included in column (7).
We rerun the regression without infant mortality to check the endogeneity of this variable and the results did not change with signs and significance.

5.6.3 Analysis of Donors' interest in aid allocation for target 7 of the MDG goals

In this part of the analysis we chose the aid commitment for water and sanitation, as mentioned in Thiele *et al*. (2007) that Neumayer (2003) considers commitments as more expressive than disbursements for their inclusiveness of the nature of the donors' power. Moreover, OECD describes commitments as a written obligation, while disbursement stands for the actual financial transactions (OECD, 2002).
We can express aid in this case as:

$$Aid_{ijt} = f(W \,\&\, S_j, GDP_j, Gov_j) \text{ for } t \in \mathrm{T}, \tag{5.9}$$

Where Aid_{ijt} is the aid for water and sanitation by donor *i* for recipient country *j* at year *t* in period T, $W\&S_j$ is the percentage of population with safe access to water or sanitation in country j, GDP_j per capita for country *j*, and the governance indicator for country *j*.

We use Tobit analysis for this part of the regression. The usage of a type II Tobit regression is a necessity as donors are selective in their provision of aid, some countries may receive aid from a donor and others may not. Donors' aid is partly continuous with positive probability mass at one or more points. Censored models are applicable in this case and all the negative values of the negative donors commitment is censored with value zero. Let aid_i^* be an unobservable censored variable for a number of observations, so that

$$aid_i^* = \beta_0 + \beta_1 X_i + \varepsilon_i \tag{5.10}$$

Where $\begin{cases} Aid_i = aid_i^* & \text{if } aid_i^* > 0 \\ Aid_i = 0 & \text{if } aid_i^* \le 0 \end{cases}$

And $\varepsilon_i \sim N(0, \sigma^2)$

In this case aid_i^* is the desired donation or provision and Aid_i is the actual aid, X_i is the matrix of the explanatory variables. A negative value for desired aid (aid*) would indicate that if possible donors would like to take money from W&S to divert to other uses.

Aid commitments for the donors are the dependent variables. Then all donors' commitment for water and sanitation target is represented by a ratio of water and sanitation aid to the total aid given by donors, because it stands for the decision taken by donors for their commitment to this type of aid. Results of the analysis are present in tables 5.7 and 5.8 covering the period 1995-2010, while table 5.9 covers the period from 2000-2010. From the regression results we can see the impact of the ratio for all donors' ODA for water with respect to their total ODA (ODA for water and sanitation/total ODA) is found to be positive and significant at the 10% significance level. As for the regressions with safe access to sanitation, the ratio of targeted water and sanitation aid is found to have a significant result for the period 2000-2010, while this ratio is insignificant in table 5.8 we find it significant at 5% significance level for the period 2000-2010 in table 5.9 That indicates the commitment increased by donors following the announcement of the MDG goals in 2000, which dedicated target 7 for both water and sanitation. Aid commitment increased as a means for achieving the MDG goal. From table 5.9, improved sanitation facilities is significant at a 5% level, and a 1 unit increase in sanitation access is accompanied with a 0.03 units increase in donors' allocation for aid for access to improved sanitation facilities. If we look through the results in table 5.7, we can see that most of the individual donors' targeted aid for water is working, but the negative sign indicates that the aid of the individual country is allocated to the countries with less or no safe access to water. France's aid which is significant at 10% significant for safe access to water (-0.129*, from table 5.7) and at a 1% significant effect for sanitation (-0.114***, from table 5.8) but results are negative, which indicates that the less the safe access to water and sanitation in the recipient countries is, the more is the aid that is allocated from France for the water subsector.

From the table (5.7), government effectiveness and GDP per capita are significant for most of the donors for water access; a 0.03 unit improvement for safe access to water is associated with a 1 unit increase in donors targeted water sector aid. From tables 5.7 and 5.9, results indicate that a 1 unit increase in governance enhances the donors' ability to allocate aid for water and sanitation with respect to total aid by donors by 1.77 units for water and a 2.3 unit for sanitation, which confirms the belief that donors target aid in line with good governance in the recipient country. At the same time lower GDP triggers the donations for water access and sanitation. In other words the poorer the recipients, the higher the targeted aid for water and sanitation. This reflects the interest of donors to contribute in reaching the MDG goals for water and sanitation. When we disaggregated the data for the donors we can see from the tables that both the GDP per capita is significant for most of the bilateral and the total multilateral donors. While the governance indicator is significant for all the bilateral donors, but what is highlighted here is the negative significant effect of governance for the aid received from the USA, which can be explained by the fact that much of aid received from the USA is for political reasons. Moreover according to Radelet (2003, p.1) the USA bilateral aid is criticized for the lack of planning and its weak effect in the poor countries, also, when the MCA[38] of the USAID was reformed to include strategic political partners such as Egypt, Jordan, Columbia, Russia and Turkey, recipient countries which are not necessarily low income countries. As for the safe access, Japan, the highest donor for water and sanitation, together with Netherlands and USA are allocating the most effective targeted aid for water and sanitation.

Our results are in agreement with Thiele *et al.* (2007), that most donors give aid to countries with better governance. That is applicable as seen for the MDG goal for water and sanitation. In general, results show that the combined efforts of the donors are affecting target 10 of the MDG goal 7 for water and sanitation. If we concentrate on the individual effort it becomes non-significant for most of the donors. Kanbur and Sandler (1999, p.29) explained how donors in their shift towards sectoral development assistance, where it is characterized by individual projects face issues like a weak impact on the sector, or maybe if coordinated between donors for these individual projects can cause a donor recipient gap for *"policy makers in developing countries have been unable to get a clear idea of the totality of activity going on in any given sector. That is, even if the policy environment is a good one, recipient*

[38] Millennium Challenge Account is a foreign aid program established by George W. Bush to provide aid for development in low income countries.

governments may not be able to coordinate the activities of donors". Moreover, some of the political reasons behind the weak results of aid for some sectors, some governments favour a specific sector over another, whether that behaviour is from the donor country or the recipient country, also political priorities can lead to allocating aid for overly served locations and sectors. The UK for example, although its multilateral spending has increased from £109m to £172m (by 58%) between 2007-2011 for water and sanitation, its allocation for these subsectors remained accounting for 2% of its total given aid. That is also observed in the UK bilateral expenditure on W&S, which has increased by 70% (£84.5m in 2010/11) it remains at the level of 2% of bilateral donations (DFID, 2012). The Off-track, Off-target (2011) report by the Water aid organization sheds the light on different reasons why aid is not focused on where it should be and why it is not reaching the deprived places most. *"Aid is not well coordinated, is only loosely targeted according to need, and its effectiveness is constrained by red tape and lack of alignment with government systems. The sustainability of services rarely receives the attention it requires. These factors in turn undermine weak capability to capture, absorb and spend funds effectively, and lead to a vicious cycle of low investment and poor performance"* (DFID, 2012, p.6).

Table 5.7: Tobit regression for donors' commitment and access to improved water resources (1995-2010)

Variable	All donors/ratio†	Denmark	France	Germany	Japan	Netherlands	Norway	Sweden	UK	USA	Total multilateral	Eu ins	Ida
Constant	9.482***	-33.522***	-25.860***	-23.499***	-96.487***	-16.409***	-4.907***	7.371***	-19.791***	-90.373***	49.278***	-35.491***	-83.990***
	(3.83)	(5.34)	(1.23)	(2.64)	(4.75)	(2.89)	(5.36)	(6.28)	(2.79)	(9.59)	92.41)	(2.41)	(4.06)
Population with safe access to water	0.033*	0.268*	-0.129*	0.079	0.525***	0.0346	0.024*	0.065**	-0.0766	0.940***	-0.12706	-0.167*	0.216
	(2.27)	(2.45)	(2.47)	(1.82)	(3.03)	(0.94)	(2.15)	(3.15)	(1.52)	(4.39)	(1.47)	(2.15)	(1.01)
Government effectiveness	1.774***	21.136***	7.941***	5.403***	10.876*	6.839***	1.231***	3.613***	4.329**	-14.754*	1.989	7.933**	6.192
	(4.01)	(5.57)	(4.76)	(3.97)	(2.03)	(5.66)	(3.45)	(5.33)	(2.72)	(2.37)	(0.75)	(3.21)	(0.95)
GDP per capita	-0.037**	-1.462***	-0.141**	-0.330***	-0.702***	-0.549***	-0.158***	-0.223***	-0.521***	-0.797***	-1.138***	-0.335***	-4.062***
	(2.75)	(6.59)	(2.70)	(6.92)	(4.19)	(8.74)	(8.43)	(6.76)	(5.98)	(3.6)	(10.41)	(3.78)	(7.85)
sigma constant	9.482***	33.522***	25.860***	23.499***	96.487***	16.409***	4.907***	7.371***	19.791***	90.373***	49.278***	35.491***	83.990***
	(61.76)	(14.52)	(27.88)	(35.66)	(149.73)	(24.76)	(101.11)	(18.45)	(19.2)	(99.37)	(41.41)	(22.53)	(19.58)
N	1907	1907	1907	1907	1907	1907	1907	1907	1907	1907	1907	1907	1907

†Ratio of W&S aid with respect to total aid given by all donors
t-statistics are in parentheses, *** significant at 1% level, ** significant at 5% level, * significant at 10% level

Table 5.8: Tobit regression for donors' commitment and access to improved sanitation (1995-2010)

Variable	All donors/ratio†	Denmark	France	Germany	Japan	Netherlands	Norway	Sweden	UK	USA	Total multilateral	Eu ins	Ida
Constant	6.114***	-24.864***	-8.844***	-3.660*	-30.042***	-2.903*	-3.457***	-5.837***	-9.886***	-103.384***	15.544***	-21.548***	-42.746***
	(10.72)	(6.09)	(4.34)	(2.19)	(4.33)	(2.17)	(7.76)	(7.28)	(5.17)	(13.28)	(4.79)	(6.82)	(5.18)
Population with safe access to sanitation	0.0153	-0.07915	-0.114***	0.017	0.112	-0.069**	0.015*	0.007	-0.145***	0.301*	-0.196***	-0.107*	-0.22
	(1.72)	(1.24)	(3.5)	(0.66)	(1.06)	(3.03)	(2.17)	(0.61)	(4.37)	(2.4)	(3.72)	(2.17)	(1.71)
Government effectiveness	2.014***	21.359***	8.284***	6.425***	14.656**	7.117***	1.267***	4.184***	4.706**	-7.17948	2.373	7.974**	6.388
	4.62	5.67	4.97	4.71	2.79	5.91	3.54	5.96	2.96	-1.15	0.92	3.26	0.99
GDP per capita	-.0378**	-1.064***	-0.124*	-0.339***	-0.653***	-0.423***	-0.161***	-.197***	-0.392***	-0.779***	-1.015***	-0.324***	-3.341***
	(2.71)	(5.34)	(2.26)	(6.86)	(3.74)	(7.18)	(8.23)	(6.15)	(4.7)	(3.43)	(9.18)	(3.49)	(6.94)
sigma constant	9.594***	33.602***	25.995***	23.722***	97.081***	16.403***	4.913***	7.426***	19.668***	91.562***	49.123***	35.770***	83.798***
	61.74	14.47	27.73	35.26	149.04	24.72	103.74	18.23	19.18	95.91	41.43	22.53	19.59
N	1906	1906	1906	1906	1906	1906	1906	1906	1906	1906	1906	1906	1906

†Ratio of W&S aid with respect to total aid given by all donors
t-statistics are in parentheses, *** significant at 1% level, ** significant at 5% level, * significant at 10% level

Table 5.9: Tobit regression for donors’ commitment and access to improved sanitation between (2000 -2010)

Variable	All donors/ratio†	Denmark	France	Germany	Japan	Netherlands	Norway	Sweden	UK	USA	Total multilateral	Eu ins	Ida
Constant	5.732***	-17.640***	-9.483**	1.645	1.907	0.223	-2.581***	-7.405***	-13.837***	-69.905***	33.074***	-16.786***	-4.314
	(8.1)	(3.44)	(3.06)	(0.87)	(0.23)	(0.1)	(4.99)	(5.09)	(3.97)	(7.11)	(8.58)	(3.55)	(0.54)
Population with safe access to sanitation	0.028**	-0.004	-0.109*	0.046	0.104	-0.059	0.022**	0.023	-0.158**	0.153	-0.202***	-0.165*	-0.118
	(2.82)	(0.05)	(2.41)	(1.69)	(0.87)	(1.77)	(3.03)	(1.18)	(2.99)	(1.02)	(3.53)	(2.34)	(0.98)
Government effectiveness	2.344***	27.528***	10.651***	9.137***	32.623***	13.047***	1.577***	5.871***	4.475	7.670	11.887***	14.972***	23.436***
	4.76	5.52	4.61	6.32	5.53	6.85	4.12	4.96	1.72	1.01	4.16	4.26	3.65
GDP per capita	-0.062***	-1.510***	-0.193*	-0.415***	-0.985***	-0.667***	-0.160***	-0.309***	-0.577***	-1.153***	-1.179***	-0.448***	-3.605***
	-3.96	-5.12	-2.56	-7.9	-5.05	-7.02	-7.85	-5.22	-3.92	-4.11	-9.8	-3.4	(7.57)
sigma constant	8.845***	31.509***	28.398***	20.391***	92.720***	18.719***	4.225***	9.255***	24.336***	94.225***	44.538***	41.042***	67.239***
	50.54	11.34	21.88	31.7	136.8	19.34	102.27	13.23	14.46	86.47	37.94	18.54	(18.83)
N	1277	1277	1277	1277	1277	1277	1277	1277	1277	1277	1277	1277	1277

†Ratio of W&S aid with respect to total aid given by all donors
t-statistics are in parentheses, *** significant at 1% level, ** significant at 5% level, * significant at 10% level

5.6.4 Effect of Geographic region on safe access to Water and Sanitation

The previous analysis reflects advancement in W&S through international efforts, but that is at the donors and the recipients' level. At the international level, we need to see the general accomplishment that is affected by the geographic regions. Usually, efforts are diluted when compared with greater special areas. The effectiveness of aid for safe access to W&S depends on the country's institutions, macroeconomy and different socio economic characteristics. Countries are nested within regions. Regions affect the effectiveness of aid and safe access to W&S. We use the multilevel modelling in exploring the effectiveness of aid within regions. Some of the advantages to using the multilevel analysis are it allow us to explore differences in the effects between groups, also giving a good idea of the variations between groups. For more explanation see Appendix 5.II. We need to answer the question do regional factors affect aid effectiveness that consequently affects safe access to water and sanitation?

We regress the change in water and the change in sanitation on aid and aid volatility using a random intercept model, where the random part is the region[39]. We gave a region a numbering category that is included in the regression. The regression results are included in table 5.10. We find that within a single region a 1 % increase in aid for water and sanitation increases the improvement in water access by 2.24 % and 1.3% for sanitation, which are small percentages. Variation between regions in the effectiveness of aid on safe access to water is 8.6%[40] while 9%[41] is the geographic effectiveness of aid on safe access to proper sanitation.

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[39] We use codes that stands for regions in the dtabase, for South Asia=1, Europe and central Asia=2, Mena countries=3, Sub Saharan Africa=4, East Asia and Pacific=5 and Latin America=6

[40] VPC= 0.0463674/ 0.0463674+ 0.4921704=0.0463674/0.5385378=0.086*100= 8.6%

[41] VPC= 0.059227/0.059227+0.5942098=0.059227/0.6534368=0.090*100=9%

Table 5.10: Regression results of the multilevel model

Dependent variable: Change in access to improved Water source		
Parameters of random part	Estimates	Standard error
ODA W&S/GDP	2.245***	0.332
Aid volatility	-0.411***	0.087
σ_u^2	0.046	0.029
σ_e^2	0.492	0.023
Dependent variable: change in access to improved Sanitation facilities		
Parameters of random part	Estimates	Standard error
ODA W&S/GDP	1.13***	0.365
Aid volatility	-0.155	0.096
σ_u^2	0.059	0.037
σ_e^2	0.594	0.027

t-statistics are in parentheses, *** significant at 1% level, ** significant at 5% level,
* significant at 10% level
Note: This regression does not include time dummies.

5.7 Conclusion

The main goal of this chapter has been to explore the effectiveness of aid for water and sanitation and what is the impact of aid on the recipient countries and also the donors' motivations driving their commitments to reach the MDG goals. The other goal is to explore other factors that may affect the safe access to water and sanitation. We verify that aid for water and sanitation impacts positively on access as does good governance. The results also indicate a governments share in financing safe access to aid is a matter of concern, good governance affects access to water as do aid, the two reinforce each other. Let's say access to water is not a high priority. Governments with a small budget will not be spending much money on it. But governments with a large budget may. However, a large government sector may be inefficient compared to the private sector. We find evidence for both of these possibilities. First, high government share increases access in rural areas, but secondly it reduces it in urban areas. Moreover, the development in one sector like a health sector has a spill over effect on development in water and sanitation, probably reflecting the concern in one area motivates concern in the other. However, with a limited budget, the allocation of aid can focus on one sector on account of the other. Developing countries too have limited resources. That is apparent in the net ODA received as a per cent of GNI results. For instance in our results the combined responsibility for the donors and the recipient governments play the dominating part in attaining this goal. Also we find that aid dependent countries are very sensitive to negative volatility of aid in agreement with expectations. There is a backward issue in the MDG target, which highlights its importance of urban and rural provision for improved water and sanitation, but there is no difference in the allocation of funds and efforts between the rural and the urban areas in deprived countries.

Results show that aid allocation by donors is to target 10 of the MDG goals is focused on governments with higher governance indicators and the poorer the country the higher the allocation of aid. That indicates a degree of consistency between the donors and the recipients. Nevertheless, different reforms for development assessment during the last decade gave more flexibility in expenditure for the recipient country, where that can be both an advantage and a disadvantage. It is an advantage where the country escapes the problems of tied aid, and a disadvantage when some governments, especially in the low income countries, are careless or do not give any effort to development. Some countries with a high bureaucracy level can cause a leaching effect of aid to specific parties or to lobbies in the governments.

Still this area of development aid needs better concern and more commitment from the global society. Several reports hint that global spending on health and education sectors is taking priority over the water and sanitation sectors. Although safe access to water and sanitation have risen significantly as our results reflect, according to Water Aid there are more people today lacking the facilities of basic sanitation than during the 1990s (Water Aid, 2012). So far, over 2 billion people have gained access to improved sources for drinking water since 1990 (JMP estimates). Although UNICEF and the WHO announced that the MDG target for drinking water had been reached, but that the sanitation target would not be met, about 780 million people lack safe access to safe water. It is apparent in figure 5.6 that about 14% of the population access unimproved water source in rural areas during 2010, and 2.5 billion people still lack proper sanitation according to WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation (JMP). See figure 5.7 which shows about 16% of the population in rural areas lack access to improved sanitation. In April 2012, donors declared in an agreement to increase the number of people with safe access to water and sanitation for the next two years. As for bilateral donors, a new joint cooperation between the Netherlands and United Kingdom is in progress to improve water and sanitation for 10 million people in nine countries in West and Central Africa. Several factors such as rapid urbanization, population density and globalization enhance the access to the best sanitation and safe water, where these two subsectors are a challenge for most of the developing countries. The off-track record in some areas for reaching the MDG goals calls for a new management and alignments of the received aid whether that management come from the donors or the recipients. That is, given the resources which are devoted to W&S, those resources need to be used with maximum efficiency. In addition to a further adaptation arrangement for the climate change issue that has its weight on the resources, and plays a critical part in development of water and sanitation sub sectors in some parts of the world, especially for Sub-Saharan Africa, that is apparent in figures 5.8 and 5.9, where 25% of population still lack safe access to improved water sources and improved sanitation facilities during 2010. In figure 5.10 we can see that in 2010 there is a 55% of open defecation[42] in rural areas in southern Asia.

All the available regression results and information pointed to the impossibility of solving the problem of access to unimproved water and sanitation in the near future. That may be affected by several reasons such as climate change consequences, where a study for the WHO (2009) organization sheds light on this fact that may hamper the

[42] Open defecation is defined as defecation in fields, forests, bushes, bodies of water or other open spaces. (The official United Nations site for the MDG indicators).

efforts to improve these facilities *"Most impacts will be experienced through more droughts, floods, and less predictable rainfall and water flows. These will place established water and sanitation services –and future gains in access and service quality – at real risk. The impacts are likely to be dramatic and severe for the billions of people who continue to seek the elusive goal of meeting their own basic needs. The effects of climate change could also cause a substantive set-back in the developed world among those who feel confident that they have secured access to basic services"*. In addition, the Eurozone economic crisis will cost the world's poorest countries $238bn and that will affect investment in poor countries, aid and trade according to the Overseas Development Institute (Massa *at al*., 2012, p.51). Also, the World Bank warned the developing countries to be prepared for a shortfall in aid due to the new economic crisis. The OECD report (2012) commented on the decrease of bilateral ODA by 4.5% in 2011.

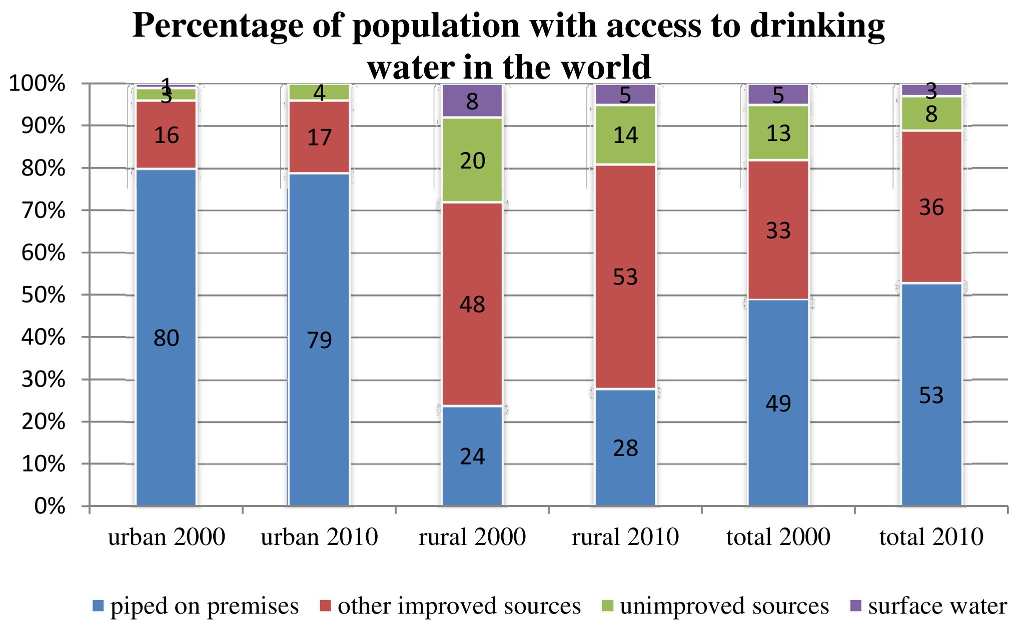

Figure 5.6: Percentage of population with safe access to improved water source- World. (Source: WHO / UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation)

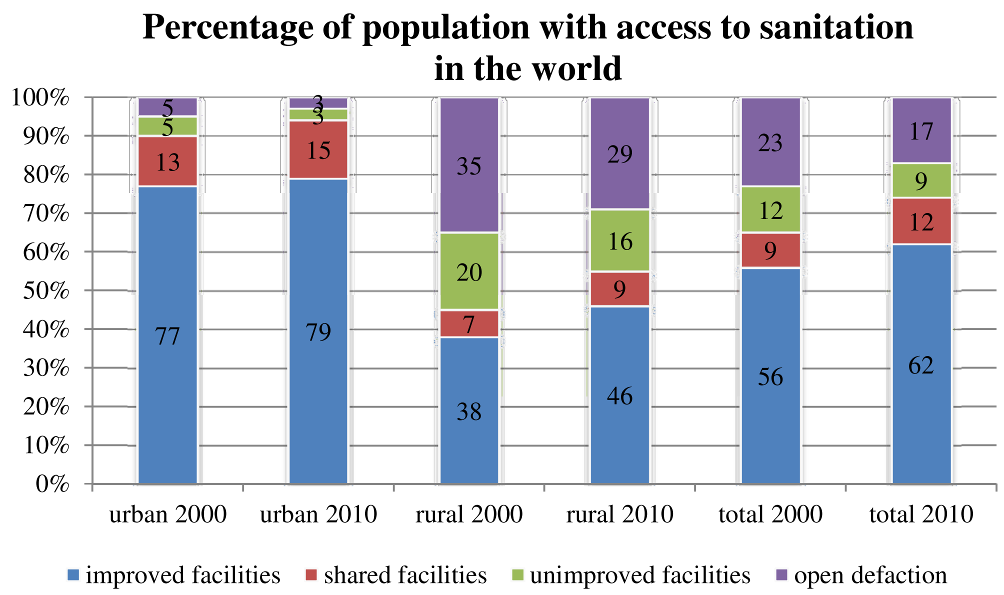

Figure 5.7: Percentage of population with safe access to improved sanitation facilities. (Source: WHO / UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation)

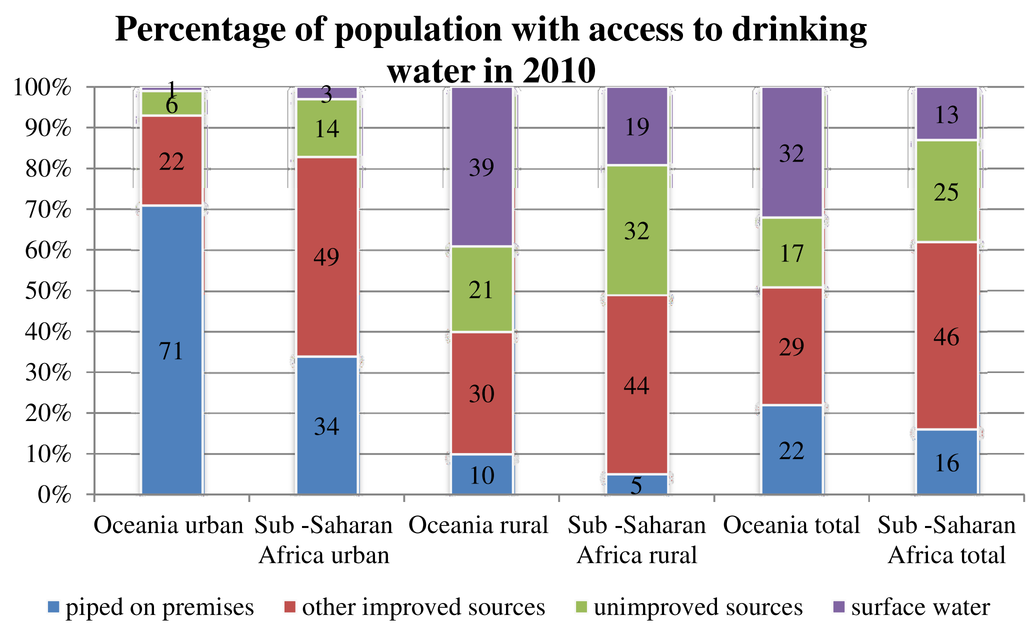

Figure 5.8: Percentage of population with safe access to improved water source in Oceania and Sub Saharan Africa (Source: WHO / UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation)

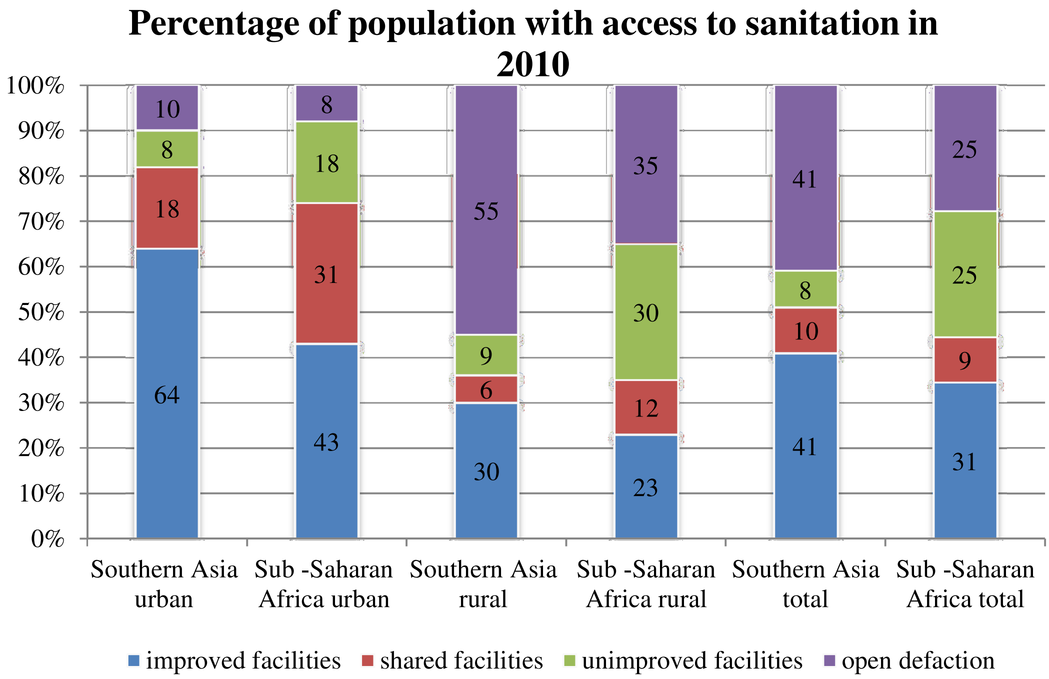

Figure 5.9: Percentage of population with safe access to improved sanitation facilities in Southern Asia and Sub Saharan Africa (Source: WHO / UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation)

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Appendix 5.I

Feasible generalized least square

It is generalized least squares estimation, GLS is applicable when variances of observations are unequal, heteroskedasticity, and when we have correlation between estimators, in this case OLS is not applicable.

Consider the Ω matrix or the variance structure of errors:

$$\underset{TxT}{\Omega} = \begin{bmatrix} \sigma_\mu^2 + \sigma_\nu^2 & \sigma_\mu^2 & .... & \sigma_\mu^2 \\ \sigma_\mu^2 & \sigma_\mu^2 + \sigma_\nu^2 & ..... & \sigma_\mu^2 \\ ..... & ..... & ..... & ..... \\ \sigma_\mu^2 & \sigma_\mu^2 & .... & \sigma_\mu^2 + \sigma_\nu^2 \end{bmatrix}$$

According to Baltagi (2001)[43] When Ω matrix is known , GLS where there is a true variance component is BLUE and the feasible GLS is asymptotically efficient where n and/or T approaches infinity. In GLS we compute theta using the Ω matrix

$$\theta = 1 - \sqrt{\frac{\sigma_\nu^2}{T\sigma_\mu^2 + \sigma_\nu^2}}$$

When Ω is unknown, we have to estimate θ using $\hat{\sigma}_\mu^2$ and $\hat{\sigma}_\nu^2$ then:

$$\hat{\theta} = \sqrt{\frac{\hat{\sigma}_\nu^2}{T\hat{\sigma}_\mu^2 + \hat{\sigma}_\nu^2}} = 1 - \sqrt{\frac{\hat{\sigma}_\nu^2}{T\hat{\sigma}_{between}^2}}$$

$\hat{\sigma}_\nu^2$ is obtained from SSE for the within estimator or from deviation of residuals from group means of residuals, when ν_{it} residuals from LSDV then

$\hat{\sigma}_\nu^2 = \dfrac{SSE_{within}}{nT-n-k} = \dfrac{e'e_{within}}{nT-n-k} = \dfrac{\sum_{i=1}^{n}\sum_{t=1}^{T}(\nu_{it} - \bar{\nu}_{i\bullet})^2}{nT-n-k}$ and $\hat{\sigma}_\mu^2$ is obtained from between effect model $\hat{\sigma}_\mu^2 = \hat{\sigma}_{between}^2 - \dfrac{\hat{\sigma}_\nu^2}{T}$ where $\hat{\sigma}_{between}^2 = \dfrac{SSE_{between}}{n-k}$

Then variables are transformed using the estimated $\hat{\theta}$ and then we run OLS transformed variables:

OLS: $y_{it}^* = \alpha^* + x_{it}^{*\prime}\beta^* - \varepsilon_{it}^*$ where $y_{it}^* = y_{it} - \hat{\theta}\bar{y}_{i\bullet}$, $x_{it} = x_{it} - \hat{\theta}\bar{x}_{i\bullet}$ for all X_k and $\alpha^* = 1 - \hat{\theta}$[44]

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[43] Baltagi, Badi H. 2001. Econometric Analysis of Panel Data. Wiley, John & Sons.

[44] Park, Hun Myoung. 2009. Linear Regression Models for Panel Data Using SAS, Stata, LIMDEP, and SPSS. Working Paper. The University Information Technology Services (UITS) Center for Statistical and Mathematical Computing, Indiana University." http://www.indiana.edu/~statmath/stat/all/panel (Accessed June, 2012).

Appendix 5.II [45]

Multilevel modelling

We use the two level where the countries are nested within the region,

Region *j*- level 2

$\downarrow$

Access to water and sanitation in country *i*- level 1

In two- level modelling the residual is split into two components, into a group random effect u_j and the individual residual denoted by e_{ij} .

The two- level models we use is expressed as

$$y_{it} = \underbrace{\beta_0 + \beta_1 x_{ij}}_{\substack{\text{fixed}\\ \text{part}}} + \underbrace{u_j + e_{ij}}_{\substack{\text{random}\\ \text{part}}}$$

Where y_{ij} is the response of unit *i* in region *j*, x_{ij} is the predictor variable of unit *i* in group *j*

β_0 is the overall intercept, β_1 is the overall slope coefficient, u_j is the level-2 random effect (or the residual), e_{ij} is the level-1 random effect (or residual error).

e_{ij} is related to the country effect and u_j is related to the region effect.

- u_j is assumed normally distributed with mean 0 and variance σ_u^2 , $u_j \sim N(0, \sigma_u^2)$, σ_u^2 is the between group variance and it measures the variability of the group means. If σ_u^2=o, then there are no differences between groups and the multilevel model is not valid.
- e_{ij} also are assumed to be normally distributed with mean 0 and variance σ_e^2 where $e_{ij} \sim N(0, \sigma_e^2)$, σ_e^2 is the within group variance and measures the variability of the response y_{ij} within groups also, $\sigma_e^2=0$ if there are no differences within groups.

In our analysis σ_u^2 is the between region variances and σ_e^2 is the within region (between countries) variances.

The level 2 or region variance partition coefficient: measures the proportion of total variance that is due to differences between groups $V\hat{P}C = \dfrac{\hat{\sigma}_u^2}{\hat{\sigma}_u^2 + \hat{\sigma}_e^2}$

[45] Rabe-Hesketh, Sophia. Multilevel and longitudinal modeling using Stata. College Station, TX: Stata Press, 2005.

Appendix 5.III

Table 5.III.1: List of 139 countries and the 53 low income countries included in the study.

List of 139 countries in the study			The low income countries
Afghanistan	Georgia	Pakistan	Afghanistan
Albania	Ghana	Palau	Bangladesh
Algeria	Grenada	Panama	Benin
Angola	Guatemala	Papua New Guinea	Bhutan
Argentina	Guinea-Bissau	Paraguay	Burkina Faso
Armenia	Guinea	Peru	Burundi
Azerbaijan	Guyana	Philippines	Cambodia
Bangladesh	Haiti	Rwanda	Central African R
Barbados	Honduras	Saint Kitts and Nevis	Chad
Belarus	India	Saint Lucia	Comoros
Belize	Indonesia	St Vincent & the Grenadines	Congo, Dem. Rep.
Benin	Iran	Samoa	Cote d'Ivoire
Bhutan	Iraq	Senegal	Eritrea
Bolivia	Jamaica	Serbia	Ethiopia
Bosnia and Herzegovina	Jordan	Seychelles	Gambia, The
Botswana	Kazakhstan	Sierra Leone	Ghana
Brazil	Kenya	Solomon Islands	Guinea
Burkina Faso	Kiribati	Somalia	Guinea-Bissau
Burundi	Kyrgyzstan	South Africa	Haiti
Cambodia	Lao Republic	Sri Lanka	India
Cameroon	Lebanon	Sudan	Kenya
Cape Verde	Lesotho	Suriname	Korea, Dem. Rep.
Central African Republic	Liberia	Swaziland	Kyrgyz Republic
Chad	Libya	Syria	Lao PDR
Chile	Macedonia	Tajikistan	Liberia
China	Madagascar	Tanzania	Madagascar
Colombia	Malawi	Thailand	Malawi
Comoros	Malaysia	Timor-Leste	Mali
Congo	Maldives	Togo	Mauritania
Costa Rica	Mali	Tonga	Mongolia
Croatia	Marshall Islands	Trinidad and Tobago	Mozambique
Cuba	Mauritania	Tunisia	Myanmar
Côte d'Ivoire	Mauritius	Turkey	Nepal
Democratic R. of Korea	Mexico	Turkmenistan	Niger
Democratic R. of the Congo	Micronesia	Uganda	Nigeria
Djibouti	Moldova	Ukraine	Pakistan
Dominica	Mongolia	Uruguay	Papua New Guinea
Dominican Republic	Montenegro	Uzbekistan	Rwanda
Ecuador	Morocco	Vanuatu	Senegal
Egypt	Mozambique	Venezuela	Sierra Leone
El Salvador	Myanmar	Vietnam	Solomon Islands
Equatorial Guinea	Namibia	West bank and Gaza	Somalia
Eritrea	Nepal	Yemen	Sudan
Ethiopia	Nicaragua	Zambia	Tajikistan
Fiji	Niger	Zimbabwe	Tanzania
Gabon	Nigeria		Timor-Leste
Gambia	Oman		Togo
			Uganda
			Uzbekistan
			Vietnam
			Yemen, Rep.
			Zambia
			Zimbabwe

Chapter 6

Conclusions, General Summaries and Policy Discussions

“People today have forgotten they're really just a part of nature. Yet, they destroy the nature on which our lives depend. They always think they can make something better. Especially scientists. They may be smart, but most don't understand the heart of nature. They only invent things that, in the end, make people unhappy. Yet they're so proud of their inventions. What's worse, most people are, too. They view them as if they were miracles. They worship them. They don't know it, but they're losing nature. They don't see that they're going to perish. The most important things for human beings are clean air and clean water.”

Akira Kurosawa, *Yume*

“It is difficult to find anything more healthy to drink than good cold water, such as flows down to us from springs and snows of our mountains. This is the beverage we should drink. It should be our drink at all times.”

Brigham Young

Water is life's mater and matrix, mother and medium. There is no life without water.

Albert Szent-Györgyi

This chapter has two main purposes. It discusses the different international policies that deal with water management and water resources, and discusses our findings with different chapters within the discussion context. First the motivation behind the work came from the increasing concern about water scarcity and quality that paved the way for different reforms in water policies and management.

There is an international consensus that scarcity of water is one of the pressing issues for development and consequently for poverty alleviation during the new millennium of the twenty first century. The UN’s Committee on Economic, Social and Cultural Rights addressed this issue in the general comment (2002): *"The human right to water is indispensable for leading a life in human dignity. It is a prerequisite for the realization of other human rights".* The Millennium development goals were issued as development goals with an explicit focus on reducing absolute poverty that will integrate with different environmental issues. Target 7.C of the MDG goals is to reduce by half the proportion of population without sustainable access to safe drinking water and basic sanitation. Water is important here for its part in human security and in its link to other Millennium Goals such as poverty reduction, gender equality, health and so on. Water security is critical for growth, development and poverty reduction (Grey and Sadoff, 2007). According to Grey and Sadoff (2007, p. 546) *"The dynamics of water, growth and poverty are complex and dependent upon specific physical, cultural, political and economic circumstances"*. Countries with huge populations, such as China, have admitted the importance of water security for growth, development and sustainability (Liu *et al.* 2007). The combination of water scarcity and lack of good resource management affects food security, health, education, ecosystem, economic growth and development. In some parts of the world women are deprived education to collect water, where in places you can see families spending half of their daily income on water. Some agricultural lands became arid areas due to the lack of water, where at the same time the lack of safe access to water and sanitation can affect the health of some people and may cause infant mortality. The future growth and prosperity of nations will be limited by water scarcity, where water management requires better policies that are shaped taking into consideration different human, environmental, social, economic, political and regional features. Water and Green Growth report (2012, P.9) prepared by the Government of the Republic of Korea and the World Water Council (WWC) addressed the fact that *"The serious environmental and water management challenges that face communities everywhere include: deteriorating water quality; inadequate access to clean water and sanitation for health; a decline in biological diversity; flooding, droughts and other natural disasters; and the need for ecosystem restoration, water treatment and wastewater management"*.

Ahead of Rio+20 conference[46] in 2012, the ERD[47] team introduced the WEL (water, energy and land) nexus that requested the EU to implement a new approach in managing the three sectors of water, land and energy in an integrated form to ensure a sustainable development and growth in developing countries. According to the report *"A drop of water, a piece of land, or a kilojoule of renewable energy cannot be seen through the single lens of one sectoral policy or management system. What might appear to be an efficient policy in one dimension can be harmful for others"* (2012 European Report on Development, p.5).

The international community is braced for more water scarcity. Societies cannot abide by the present limitations in water resources any longer. Population growth puts main stress on water resources in a way that the demand increasingly exceeds the supply. This problem is getting more serious for lots of countries that suffer from high population density in some regions. This trend is likely to continue as water withdrawal is projected to increase by at least 50% by 2025 compared to the 1995 level (Rosegrant *et al.* 2002). Mollinga (2000, p.14) considered safe drinking water as a part of food security. The link between water security with food security is triggered by economic growth that stimulates the productivity into agricultural sector. For the fact is that water resource development integrates social factors with economic development and environmental quality and is needed for sustainable development. The November 2012 a report by the World Bank *Turn Down the Heat*, declared that the Mediterranean, North Africa, Middle East, and the United States are facing an increase of temperature by 6° C by 2100. This temperature rise can lead to food and water scarcity, where flooding, heat waves, droughts affect the food supply. All these issues concerning water and food scarcity call for more water management. Furthermore, a distinction between rainfed agriculture and ground water withdrawal for agricultural purposes should be taken into further considerations. For example, Calzadilla *et al.* (2010) analyzed the economic benefits

[46] Rio+20" is the short name for the United Nations Conference on Sustainable Development which took place in Rio de Janeiro, Brazil in June 2012.
[47] The ERD (European Report on Development 2011-2012) team was led by the Overseas Development Institute (ODI), in partnership with the European Centre for Development Policy Management (ECDPM), and the German Development Institute / Deutsches Institut für Entwicklungspolitik (GDI/DIE).

from ground water management, at national and international levels by analyzing traded agricultural products (crops) and found that by 2025 where there is a mismanagement of groundwater it leads to a decrease in the production costs, the global irrigated production of crops increases by 9.9 percent while global rainfed production decreased by 6.7 percent; as a result, total production according to their calculations, increased slightly by 0.4 percent. Generally, the irrigated crops increase in all regions, while the rainfed production will decrease in all regions. In this case, global irrigated production increases for all crops by between 7 to 13 percent. While on the other hand, when there is a sustainable management of groundwater resources, blue water use decreases by 2.76 percent for crop production, and irrigated crops production decreases between 1.0 to 3.2 percent for all crop types. However, global rainfed production and green water use increase by 1.4 percent and 1.5 percent. This is a clear example by these researchers illustrating the importance of management of irrigated and ground water resources.

And as Mark Twain said that *"whiskey is for drinking and water is for fighting over"*. Political reforms become a necessity for water scarcity. The pressing issue of water security has created conflicts over most populated water basins in the world, which needed several international agreements over water management and the reforms of different international policies. As an example, we have a Compliant Agreement in the Nile Basin, which led to sign on new treaty between the upstream countries (Ethiopia, Kenya, Rwanda, Tanzania and Uganda). This Cooperative Framework Agreement will create laws and institutions to manage the water withdrawal of the Nile River (Water Link, 2010). Another examples of conflict, as the conflict on dams on the Euphrates between Turkey and Syria (Jongerden, 2010), also the conflict between Pakistan and India over the irrigation canals (Wolf, 1998). This conflict over water is a reflection of the conflict to survive, conflict of the power of the economy.

6.1 Summary of my work within this context

In chapter 2, we modeled the role of water scarcity catching the two ends of stake scarcity and constraint, the ratio of water utilization and water quality, both stand as a proxy for water scarcity[48] in an endogenous economic growth model. The definition of water scarcity embodies several concepts, such as water crisis. Water utilization proxies for water scarcity, where it is the ratio of water withdrawal with respect to renewable water resources, where high water use and deterioration of water quality around the world are putting great pressures on water resources, *"Degraded water quality is often associated with water shortages and exacerbates the effects of water scarcity"* Pereira *et al.* (2002, p.7). Some literature has explored the effect of environmental quality within the endogenous growth model. Elbasha and Roe (1996) examined the interaction between endogenous economic growth and the environmental quality which is represented by pollution abatement. Dinda (2005) examined the relationship between income and environmental quality (pollution) in endogenous growth model to explain EKC (Environmental Kuznets Curve) in the endogenous growth model, to find that using all the stock of capital in production produces pollution and damages the environmental quality. Consequently, economies should perform pollution abatement to keep their environmental quality, in other words, they should move to invest in pollution abatement to maintain growth. We explored the impact of environmental variables in an endogenous context where most of the previous literature modeled the impact of water in an exogenous economic growth model or exogenous GDP per capita. We concluded that although water scarcity affects and impacts on growth in the shorter and the longer run, water quality proved to have the highest significant impact in both the short and the long run. In other words water crisis is significantly affecting growth on the short and the long run. The impact of water scarcity and water quality were addressed previously by Briscoe and a World Bank team (1993) as a priority to be solved in order to improve development in rural areas.

[48] Water scarcity involves water stress, water deficits, water shortage and water crisis. A water crisis is a situation where the available potable, unpolluted water within a region is less than that region's demand. (http://en.wikipedia.org/wiki/Water_crisis).

Our estimation results illustrated the significant impact of the quality of water on growth. We concluded that although water quantity affects growth, water quality is a higher factor that affects growth more. This reinforces the work of Cook and Onjala (2009). They addressed the contamination of the surface and ground water as a *second major environmental sustainability component in water supply.* Households are highly vulnerable to contaminated surface water where the treatment costs are extensively high. Also, usually in regions that are suffering from water scarcity, generally it is accompanied with low water quality, where the ground water causes high salt contamination when extracted for surface water (Pereira *et al.,* 2002). We see in chapter 2 from the results that BOD (water quality) impacts adversely on growth. The intrinsic value of the resource is reduced and the costs of the affected quantity or the treatment of the disposal are incurred. But to an extent, more than water shortages, this is solvable. In this case the clean technology environmental management tool proves to be the best tool for pollution abatement and in reducing costs. That calls for the introduction of new techniques in water management and treatment.

As long as the usage of water and the quality of water are affecting economic growth, there is a plain need for the intervention of technological advancements to treat the scarcity of water, and also to alleviate the effect of water quality and the pollution on water resources. That is not just adding a further burden to the amount of water that is suitable for use, but also is adding costs to the production process in different economic sectors. Using policy tools and economic motivations can be an incentive in technological advancement. Some technologies like desalination (sea-water reverse osmosis technology), treat/recycle water (sewage treatment technologies) and use water efficiently (drip irrigation), can be a substitute for the scarce input or enable a more efficient use of that input (OECD, 2010).

In chapter 3, the focus has been placed upon the credibility of the fixed effects model in analyzing the effect of water scarcity and quality on GDP per capita and growth. We want to explore how the environmental variables within our work are behaving and how they are affecting growth. We found that the difference from the mean of the variables are the main impact of the variables on GDP per capita and growth, where fixed effect is expressing this relationship in capturing the influence of the difference from the mean of the variables in the models. These findings have important implications and reflect as well that *"Many countries have sufficient water to meet demands for all uses. However, much of the rainfall and river flows are highly seasonal, so there is excess at some times and not enough at others. Domestic and industrial uses require water every day, and demands may be even higher in the dry season. Agriculture can accommodate seasonal flows of water, but irrigated production in the dry season is often the most productive and profitable type of farming"* (Meinzen-Dick and Rosegrant, 2001, from report for International Food Policy Research Institute). The shadow but the critical part here is the lack of good management for water resources, which calls for more experts in water management, especially in developing countries. We found that countries usually adapt to their environmental circumstances, but what affects growth in the short and the longer run is the difference from the mean of the variables i.e. their variability. That can be explained through different channels, one of these channels is the climate change effect on water resources, the fluctuations in the weather conditions that can cause chaos through floods and droughts. Other channels can be the regional influence, the geography and the nature of the land.

The scarcity of water is one of the most pressing issues that needs further attention and is critical to solve the socio-economic and environmental issues that face the world. In chapter 4, we explored the socio economic impacts on water withdrawal for different economic sectors, to find that water withdrawal for one sector stimulates withdrawal for another sector and economic productivity as well, we tried to emphasize the role of water here as an input in industry as any other input, say labor or capital. It assists the recognition of the important role of water in economic productivity; we noticed and concluded a spillover effect of activity in one sector to the other sector. Water usage here reflects the tradeoff between different human and economic activities. This also sheds light on the amount of tariff that is applied in different countries towards water supply. In a study for the World Bank Water Demand Research Team (Briscoe and the World bank water research team, 1993) addressed the fact that the socio- economic factors play an important part in the willingness to pay for an improved water supply. *"Water is probably the only natural resource to touch all aspects of human civilization from agricultural and industrial development to the cultural and religious values embedded in society"* (Koichiro Matsuura Director General of the UNESCO). That leads us to reconsider the Target 10 in the MDGs, this target considers only the social part of water and not the usage of water for different economic sectors. It covers water for people and not water for agriculture and industry. The introduction of the effect of water quality on growth in chapter 2 assists the link of sustainability with water quality, which explains the relationship between different MDGs, where environmental quality is directly attached to pollution abatement. This calls for more investment in water and sanitation, where this leads us to explore in more details the international effort to reach the MDG 7 in chapter 5.

The lack of adequate water and sanitation in developing countries triggers the efforts from the international community, to improve water supplies by e.g. declaring the 1980s as the United Nations' International Drinking Water Supply and Sanitation Decade. Further commitment was endorsed in 1990 in the New Delhi Global Conference on Safe Water and Sanitation. Chapter 5 sheds the light on the importance of aid to water and sanitation sub sectors, emphasizing the importance of these two subsectors on economic development and the alleviation of poverty. To analyze the outcomes of the international efforts in improving these subsectors around the world, we concentrated on the effect of aid in different regions, we have seen that a 1% increase in funds lead to a 1.4% increase in safe access to water in rural areas for the recipient countries. This needs further attention by the international community to increase this percentage, usually urban areas have more access to water because there are installed pipes and reservoirs for water, while most rural areas in developing countries are deprived of pipes or reservoirs. The efforts are quite near to accomplishing the millennium development goal, but extrinsically there are still millions of people around the globe deprived of safe water and proper sanitation. After the financial crisis, doubts increased towards the ability of these two subsectors to meet their goals. The lack of good management with weak institutions highlighted the need for good public finance as an important tool for provision of public infrastructure. That highlights the role and the efforts of the NGOs in practicing advocacy of the rights to safe access to water. The OECD report (2010) discusses the innovative financing mechanism as a possible and a promising factor that can help to improve the financing of water and sanitation services, where the weak point for this mechanism is the long process it takes in making the arrangements, which is related to weak institutional systems, and also to the lack of the cash flow needed for costs. Some bilateral and multilateral aids play a microfinance part and are given as loans for water and sanitation at the national level (Cook and Onjala, 2009).

We can see from the previous results that quantity, quality and safe access to water require further international movement. We try next to discuss some solutions and within our context and from different perspectives to interpret with our previous results in this light. Also, we need to mention the effect of climate change on the availability of water, where the installment of a good infrastructure and sustaining the present infrastructures are priorities for water supply and sanitation. Building upon our results that are discussed above, we look at some literature that embodies discussions about the possible solutions that can alleviate the effect of water scarcity in its general meaning and triggers water security.

6.2 Solutions

Integrated water management embodies the management of irrigation, drinking water, industrial use, and the ecology of water (Mollinga, 2000). Good management of water resources increases the chances of better green economic growth and better adaptation and abatement of the climate change effects on water resources (Grobicki, 2010). In addition to taking advantage of cost-effective, water conservation technologies, water storage capacity and practices that are widely present in different countries and have succeeded in water management, need to be adopted more widely. Other considerations must be given to the groundwater deterioration, especially where food security is a stressing issue that stimulates more extraction of groundwater for irrigation purposes. Leaving an urgent need for solutions for these issues, where at the end, the more serious issue is not the management of groundwater but the sustainable management (Shah *et al.* 2000).

The concept of virtual water Trade (VWT) was introduced in 1993 by Professor Anthony Allan[49], who noticed that most of the water stressed countries, such as the Middle East countries, compensate for this scarcity in water by importing their crops from other countries, in such a way that the water can be allocated to other uses and sectors. The concept can be a starting point to set up a series of international regulations that motivate the concept of virtual water trade. But how? By regulating new kinds of policies that restrict or inhibit the production of water intensive crops in water scarce countries, these countries can compensate by importing these crops, while the contrary can take place in water rich countries (Horlemann and Neubert, 2007). Consider for example Israel, Jordan, and Saudi Arabia. They suffer from water scarcity, have quit crop production and are using their water heavily for domestic and industrial uses, while importing 75 to 95 percent of their grain (Brown and Halweil, 1998).

6.2.1 Institutional Effect

Water institutions play an important role in the allocation of water resources. Institutions *"create order and relative certainty for water users, which facilitate the achievement of economic and social goals"* (Livingston 1998, P.19). Moreover, Briscoe and the World Bank research team (1993) highlighted the importance of the suitable policies, in

[49] the concept compensate for the kind of data that is used to stand for how much water is demanded in the country, in other words not all the food produced by water withdrawn is consumed in the same country, some of it can be exported to be consumed elsewhere (Hoekstra and Chapagain, 2007).”*The aim of VWT is to compensate for water shortages through the geographical shift of agricultural production and the sectoral shift of water consumption”* (Hoekstra AY, Chapagain AK , 2007, pp.1).

controlling the demand for water, in order to improve quality of the supplied water in rural areas in developing countries. Institutional reforms for water management can trigger improvement in water consumption and can alleviate the effect of climate change in different parts of the world. Current and national laws in the individual countries facilitate the applications and the follow up of the laws. To apply innovative technologies and reforms in irrigation management for example, strong integration between the applied policies should be attempted. Institutional reforms and adoption of reforms that considers irrigation, green taxes, water management, and water pollution abatement are vital parts in the application of policies, adding to the important part that is played in water pricing policies. For example, Molle and Berkoff (2007) highlight the influence of institutional factors in water pricing, which we are going to discuss later. There is some discussion in the literature of the importance of policies for the sustainable management of water, especially groundwater resources. Policy makers should take into consideration the role of institutions in impacting on their plans in attaining environmental, social, and economic development.

6.2.2 Microfinance

Recently the important role that microfinance plays has been widely recognized in providing the required funds for water supply and sanitation in poor areas. The microfinance term came from the idea of innovative financing that was introduced by the OECD report, where the need was triggered by the influence of corrupt and poor management of the received funds. From an executive summary of the report issued by Global Water Challenge, case study Kenya *"for using innovative financing mechanisms to sustainably improve water supply and sanitation in Kenya. The term "sustainable" is used in the financial sense, i.e. a lack of external donor support over the long-term, and in the environmental sense, defined in terms of watershed protection".* The idea of microfinance in water and sanitation in the first place comes from retail loans that are used to provide water storage and probably to provide pipes for water and sanitation installments and for household facilities in rural areas. Other kinds of microfinance embody loans for small and medium enterprise which can be sellers of water or public providers for water or sanitation services for the low income regions in cities or crowded towns. Furthermore, the third kind involves urban services upgrading and shared facilities (Mehta, 2008; Cook and Onjala, 2009). Successful implementation of microfinance for water and sanitation requires good integration of projects and appropriate implementation of policies.

6.2.3 Policies concerning water pricing

In chapter 2 we discussed that water needed to be treated as an economic good; also we addressed the significant effect of scarcity on economic growth. In chapter 4 we illustrated the fact that water is a social good as well. As we have seen in chapter 4 from the results, there is a competition between different economic sectors for water withdrawal, at the same time, productivity in one sector enhances productivity in the other and consequently enhances the withdrawal for different sectors. That calls for a solution for managing scarcity, by using water pricing tools to regulate water consumption. How can we mobilize the political will necessary to introduce policies to address this? By enhancing the establishment of an international political framework that lists water resource management, water utilization and the safe access to water and sanitation as priorities on the political agenda. According to Johansson *et al*. (2002) *"Getting the prices right"* is a good tool for improving the water use efficiency. Water pricing is not a complete solution but can be considered as an effective tool to treat unmanaged water withdrawal; different factors affect these policies, such as the demand from different economic sectors, the institutional framework and governmental policies and spending.

Generally, to apply environmental policies we need to take into consideration that there need not, in the long run at least, be a tradeoff between the environment and economic growth. Higher growth should be a stimulator for good environmental sustainability that would enhance sustainable economic growth and prosperity. We conclude from all the results and the discussions in different subjects concerning water policies that meshing development and environmental sustainability will be no easy task. Governments need to find ways to encourage a more inclusive and sustainable growth pattern and stand up to their responsibilities. Briscoe (1996) in reviewing the data of three factors, the value of water, the use and the opportunity cost of water indicated very little amount was given to the value of water used for irrigation. The OECD countries set charges that are used to finance water management and for protecting watersheds, where these charges tend to be higher for ground water. From figure (2.1) in chapter 2, we notice that the agricultural sector is the largest actor in water withdrawal, where this sector is directly related to food security in every region. Tsur *et al.* (2004a) conduct an empirical analysis on water pricing in South Africa, Turkey and Morocco. They find that water pricing for irrigation within the agricultural sector has a minor effect on income distribution and consequently policies concerning water pricing should be independent from other policies dealing with income. Although in some cases they found that smaller farms are more sensitive to changes in water prices, and that can be due to the specialization and restrictions for some farms.

There is no specific consensus held by economists and policy makers concerning the concept of an optimal water-pricing policy. Take as an example, Israel, the semi-arid area, developed an integrated water management system that manages surface and ground water as well. This was because the increased withdrawal in global water use recently depended on groundwater (Villholth and Giordano, 2007) and that causes the deterioration of the ground water resources. They apply a new pricing mechanism to water demand policy that was modeled using basic economic tools with the incentive mechanisms. The result is the multi-level water tariffs where the agricultural sector pays lower prices than the industrial sector and which in turn pays lower prices than households. Also, they price water due to region and transportation cost, and prices paid due to consumption (OECD, 2009).

Volumetric water pricing[50] is important for a sustainable water system that needs steady finance by collecting the required revenues to feed the operating costs. That would help improve the provision of water, plus giving the donors to water access's projects more certainty about the employment of funds in the right places. Synergy and international agreements are required in supporting political actions, which would help the economic incentives to improve water and sanitation services and water management, particularly in developing countries, arid and semi-arid area of the globe. Generally, the case is expressed concisely by Molle and Berkoff (2007, p.21) *"A water charge may be a financial tool aiming to recover all or part of capital and recurrent costs, recurrent cost recovery being particularly critical to preserve the physical integrity of the system when public funds are not forthcoming. A water charge may also be an economic tool designed to conserve water and raise water productivity by promoting: (i) careful management and water conservation; (ii) cultivation of less water-demanding crops and investments in water-saving technologies; and (iii) reallocation of water to high value agriculture and/or other sectors".*

6.2.4 Pollution charges

Pollution is a by-product of regular economic activity. The most common surface water pollution that is widely discussed in the literature is the eutrophication[51] , which may result from agricultural run-off carrying fertilizers. Thus, pollutants that are discharged on the surface of the land, pollutes surface water, aquifers and the ground water resources. Treating polluted water added operational costs for businesses, it also a substantial contributor to the water crisis, where in chapter 2 we find that water quality standing for water crisis affects growth highly in a U shaped curve on the short and the

[50] Charge the price for water depending on a measurement of the volume of water consumed.
[51] Eutrophication can be defined as *"The process by which a body of water acquires a high concentration of nutrients, especially phosphates and nitrates. These typically promote excessive growth of algae. As the algae die and decompose, high levels of organic matter and the decomposing organisms deplete the water of available oxygen, causing the death of other organisms, such as fish. Eutrophication is a natural, slow-aging process for a water body, but human activity greatly speeds up the process."* Art, (1993, p. 196). Eutrophication can be from nature or human made.

longer run. According to the World Development Bank report (1992) water quality deterioration and surface water pollution are aggravating problems in developing countries. Costs of treatments depend on the pollution and the way it originates from a point source or a non-point source, the size of disposals or discharges and the area of the polluted location. Institutional factors and governmental regulations are important for limiting the effluents due to different business practices. According to Tanji, and Kielen, (2002) industrial and municipal wastewater may be disposed of without sufficient treatment and in some parts of the world they are not treated at all. Policy makers are quite aware of the importance of abatement, but in most cases are worried about the abatement costs. Usually, to propose a cost effective regulation within the individual country, it is important to estimate the abatement costs first. Where the abatement cost is determined by the records for the costs of pollution control instruments used by businesses and the benefit of abatements (Dasgupta *et al.* 1996).

One of the most effective tools to achieve policy objectives is to charge for disposals and to set fines for untreated disposals from businesses. Charges on disposals can promote water quality and ease the effect of water pollution on growth (Molle and Berkoff, 2007). For example, water quality legislation in the European Union, has been applied to control the amount of eutrophication. Atkins and Burdon (2005) conduct a cost benefit analysis. The costs related to water treatment while the benefits were determined by a contingent valuation survey to examine the effect of water legislation in controlling eutrophication and water quality improvement of the Randers Fjord in Denmark. This was used to find a good indicator of a willingness to pay among locals and the need for further costs to reach the legislations' target. In some OECD countries they charge treatment costs on disposals, where there is a tendency to separate water charges from water disposal treatment charges to ensure better pollution abatement (OECD, 2010). Treating drainage water[52] to reuse for industrial and agricultural purposes, can be a

[52] Drainage water is the unconsumed amount of the irrigation water previously used for crops. In other words, in irrigation, part of it that is not consumed by corps and ends in drainage, can be reused. (Willardson, *et al.* 1997).

solution for supplying water in water scarce places, and at the same time can be a solution for reducing the amount of disposal problems that helps in solving substantial amount of water pollution. On the other hand, reusing of drainage water for irrigation purposes can alleviate the effect of water pollution (Tanji, and Kielen, 2002).

6.2.5 Technology

Innovation is vital to face the challenges of water quality, safe access to proper water and phase out the effect of droughts and floods. When scarcity becomes an issue for survival, new solutions should be invented, especially for areas where the irrigation water is scarce and are highly populated. Using irrigated water efficiently can be a good tool for meeting the demand for food and alleviate the effect of water utilization. Technology here is a good solution to meet the need for irrigation, industrial and domestic sectors at the same time. The widely used process for irrigation in a substantial amount of countries is the drainage water reuse, such as in Israel, where they apply this technical solution within their management policies. In the previous paragraph we explained some points about the drainage water reuse. The technology involved here is improving of the drainage water quality. Several technologies are now used for water treatment, sewage treatments, improving the quality of drinking water and so on; for the fact that the water quality is directly determined by the disposals. The main common procedure is the cost effectiveness method, which depends highly on diagnoses of the kind of treatment to be used, the available methods and the area of land. The most useful used method for drainage treatment is the biological treatment, which involves the treatment of both the organic and the inorganic contaminants in the treated water (Madramootoo *et al.* 1997). Moreover, water recycling and the reuse of treated water from domestic and industrial uses can help in decreasing the utilization of water (Grobicki, 2010) and can nourish industrial and agricultural sectors especially in water poor countries. Technology can help in using water more effectively in houses, buildings, industries, agriculture. In reducing water loss from the system and in the recycling and reusing of water. It, together with changing behavior, is a key to the future. But will the research resources focused in the north; be used in time to help provide solutions for the south. By 'in time' we mean, before the water crisis becomes a disaster.

6.3 Postscript

We conclude from our results in chapter 2 that although there is a scarcity of water which is affecting growth, what matters more is the quality of water that is affecting growth significantly, which calls for implementing further efforts in technological developments for more efficient water resource management, whether they are ground or surface water. Furthermore, our results in chapter 3 support the case that the quality of water is important for economic growth and development. The case that, countries adapt to their quantity of water and what is affecting the economic performance is the variability of quantity and quality and this is illustrated in the effect of the difference from the means' effect on growth. Furthermore, the highest withdrawal for water resources is the agricultural sector, and we have seen in chapter 4 that the increase in productivity in this sector, enhances productivity in other sectors, the industrial and the service sector, which has a motivation for increasing the withdrawal that lead to a competition for withdrawal of water between the different sectors, that illustrates the fact that is pointed to in the UN report coping with water scarcity *"Water is essential for all socio-economic development and for maintaining healthy ecosystems. As population increases and development calls for increased allocations of groundwater and surface water for the domestic, agriculture and industrial sectors, the pressure on water resources intensifies, leading to tensions, conflicts among users, and excessive pressure on the environment. The increasing stress on freshwater resources brought about by ever rising demand and profligate use, as well as by growing pollution worldwide, is of serious concern"* (UN, 2007, p.4). Coping with the quality of water, on the other hand, proves the importance of aid and the effect of aid volatility for the safe access to water and sanitation, the importance here lies in the role of safe access to water and sanitation in economic and human development, where according to the UN report (2007, p.6)

"Historically, large-scale water development projects have played a major role in poverty alleviation by providing food security, protection from flooding and drought, and expanded opportunities for employment". Where an increased effort proved its role in improving the safe access to water, although as we have seen in chapter 5, funds can be politically biased, aggregated efforts are working at a constant pace. But I reinforce the point made earlier; aid is the only part of the package the North can give to the South. Technology is another point. Then of course there is the responsibility of each country, each government, each firm and customer to recognize their responsibility, and act accordingly to their resource constraint.

6.4 Limitations of the research

Several limitations to this kind of research need to be acknowledged. The main limitation that we faced in this research is the lack of a times series data for renewable water resources and for water withdrawal across a wide range of countries. In chapter 2, we had to collect the data from different resources using Gleick databases and the AQUASTAT database as a source for some data. Moreover, the units of evaluation of water resources and withdrawal are the same, for these reasons we use the data from the AQUASTAT database supported by Gleick's water databases (Gleick, 1998 and Gleick, 1999). The reason for this is to create a higher credibility by getting more accredited data. The annual fresh water withdrawal obtained by the AQUASTAT is in units of 10^9 cubic meter/ year per capita. In chapter 4 we interpolated the missing data of water withdrawal for different economic sectors. Whilst there are precedents for this, it would be better to have actual data. In addition, we lacked data for the national public expenditure on the water and sanitation subsectors. The data on aid from the CRS data base was sufficient to allow analysis. But again the value of this data base will increase as more annual data becomes available and this will allow more sophisticated analysis of, e.g., the interactions between different countries. Is it the case, for example, that donors tend to allocate aid regionally, where bye all countries in a region see aid increases or decreases together?

6.5 Identifying areas for further research

In terms of the econometrics, further work is needed on the use of fixed and random effects and also on the distinction between long and short term impacts. More recognition of the importance of the environmental data is recommended. In addition further analysis of ground and surface water pollution and its impact on economic growth is desirable. Most of the literature has concentrated on case studies or pollution of water resources in general. Further and more detailed analysis of the nature of pollution and its causes is desirable if we are to understand how to reduce its impact on growth, and indeed health. Further research is also needed to explore the relationship between water withdrawal and the water management methods that are applied in an individual country at a microeconomic level. Better management of resources is critical to the future when demand is likely to increase, but resources are largely finite. In addition, it must be recognized that not the same management methods will work in all countries equally, but a large number of course will. A number of possible future studies using the same methods as in this thesis can be applied for a single region, but in more depth. I would suggest studying the Middle East and North Africa (MENA) region that is suffering from water scarcity and the lack of the appropriate environmental policies is of particular importance to study. This region is of course politically volatile and reducing the constraints placed on countries by water limitations may help reduce these pressures. Or to put it another way, limited water resources can only add to the political tensions in giving these countries something else to fight about. But this is not just true of this area but others too, e.g. the Far East. Further research is also recommended into the possibility of improving the provision for W&S in the rural areas in the developing countries. Finally there is a need to shed light on the possibility of implementing a suitable microfinance framework and how to motivate governments to implement these policies.

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